THE

POPULAR SCIENCE MONTHLY.

MARCH, 1874.

THE WORLD BEFORE THE INTRODUCTION OF LIFE.

By CHARLES H. HITCHCOCK, A. M., Ph. D.,
PROFESSOR OF GEOLOGY IN DARTMOUTH COLLEGE.

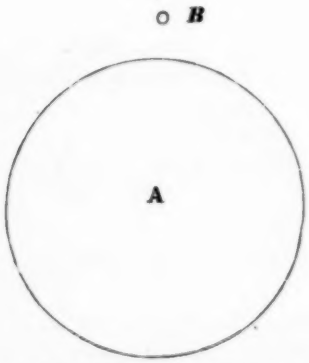
THE few hints afforded by geology respecting the earliest stages of the earth's history, when compared with studies into the nature of nebulæ, comets, and suns, suggest the existence of a series of mutations through which worlds destined for the occupation of intelligent beings must pass, in order to be properly fitted for the residence of mind. There is, first, existence as a nebula, or comet; second, the condition of a burning sun; third, a stage of refrigeration; fourth, a period of habitation by the brute creation; fifth, a time of occupancy by reasoning, moral beings; and, perhaps, sixth, a stage of frigidity, impoverishment, and extinction of life. Our planet seems to have passed through four of these stages of growth, with the fifth well advanced toward its meridian.

The history of the world might be correlated with a certain species of organic cycle, the growth of grain. There is presented to us a kernel of corn containing within itself the elements of vital action. So long as it is stored in a granary it is quiescent, but when planted in the soil it germinates, producing first the tender blade, then the tasseled tops, the silky ears, and, finally, rows of mature kernels upon the spike, inclosed by a sheathy covering. As soon as the seed is properly situated for development, an inward impulse urges onward the growth till the process is completed.

Alike fraught with instinct has been the serial progress of the earth. It first presents itself to view simply as a mass of inorganic material, a heterogeneous mixture of elements, inert and motionless, the "chaos" of theological writers. But this material is endowed with activity; the atoms possess affinities for one another, and the mass cannot remain motionless in space, surrounded by worlds and systems. Gravitation causes the mass to rotate upon its axis and to

revolve about other bodies, and chemical affinity unites the atoms into compounds. Henceforth there will be no cessation of activity till the mature condition, it may be of eternal desolation, has been attained.

FIG. 1.



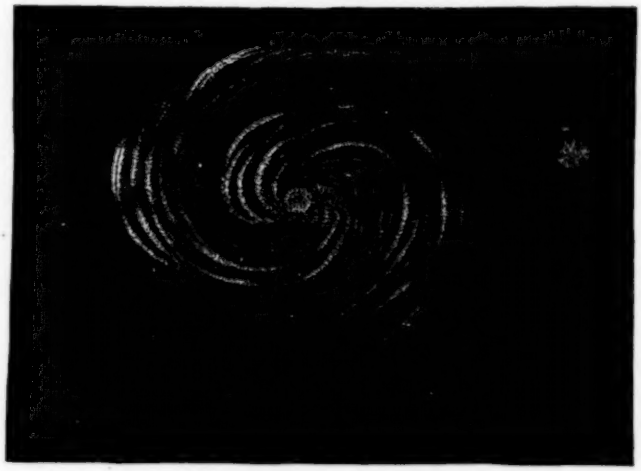
A—SIZE OF EARTH WHEN IN THE NEBULOUS PERIOD, COMPARED WITH ITS PRESENT DIAMETER, AS SHOWN BY B.

Bernard von Cotta styles these successive phases of development *stadia*, and reduces their number to seven. He conceives that during the first stadium only one agency—gravitation—acted upon matter, the results being a spherical aggregation of the particles and the production of an intense degree of heat. The second stadium adds to gravitation the agency of heat and other physical forces. In the third, chemical affinities are developed, and a cooling globe is the sphere of their action. The fourth stadium brings to view water, with its ability to accumulate formations by deposition of detritus. In the fifth, life and the power of organization are introduced. In the sixth, ice first appears. Last of all comes Mind, the other activities being present also with it.

This theory is beautifully elaborated in his interesting memoir; but its consistency with the following statement is not readily perceived: "Since the history of the development of matter is for us absolutely an infinite series, it is impossible to recognize, or even to conceive, a real beginning of things. We must enter arbitrarily into the infinite series of events, and follow it from that point down to the present time." The organic cycle commencing with the kernel of corn may repeat itself endlessly; but we demand, eventually, whence came the first seed? So we can follow back the grand cosmical series of mutations to a point antecedent to which there is nothing rational but the presence of the Infinite Mind, the same that sustains all Nature in its present activity. Progress implies a beginning. Following out the argument to its legitimate extent, we are forced to the conclusion that the Almighty actually created the material of the solar system out of nothing. Matter could not have existed from eternity, else the

phases of growth had all been completed, and we should have passed beyond the period of organic activity. The New-Zealander would have leaped over the ruins of London, and the "last man" of Hogarth would have finished gazing upon the ruins of intellectual activity.

FIG. 2.



SPIRAL NEBULA IN CANES VENATICI (H., 1622).

COSMICAL ANALOGIES.—Space is full of bodies resembling our earth in all stages of its growth. The earlier stages are displayed in nebulæ, comets, and suns. The former, by the improved methods of modern investigation, are clearly shown to be in a gaseous condition, intensely heated, though not so hot as the sun, and so tenuous that the brightness of the stars behind is hardly dimmed.

There has been great progress in the study of the nebulæ. Many had been resolved into clusters of small stars by the more powerful instruments of recent manufacture, so that astronomers doubted the existence of any unresolvable forms. But, in 1866, Mr. William Huggins showed that nineteen out of the sixty nebulæ seen through the great reflecting telescope of the Earl of Rosse presented spectra exhibiting the bright bands indicative of heated luminous gas. Hence the world could no longer doubt the settlement of the question whether any of the nebulæ are composed of vapors. Prof. Young says that the majority of the nearly 8,000 known nebulæ are luminous clouds of heated gas, with minute solid and liquid particles scattered through them. In a recent number of THE POPULAR SCIENCE MONTHLY, Mr. F. W. Clarke has classified these bodies, suggesting that there may be a law of development among them. The most distinct are composed of nitrogen and hydrogen, possessing a temperature beneath that of the sun. He propounds the hypothesis whether nebulæ may not pass by degrees into suns, the sixteen elements known to exist in

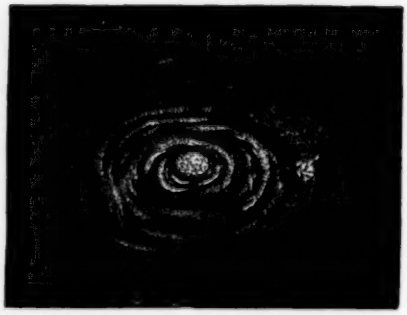
the latter class having been evolved by degrees from the original simple gases of the nebulæ. This is a problem well worthy the study of chemists.

The comets differ from nebulæ by possessing a bright, star-like nucleus, apparently more solid than the surrounding coma or brush trailing behind. The spectroscope indicates that the entire material of comets is similar to the gaseous nebulæ. Possibly their nuclei are centres of attraction around which the heavier atoms are gradually falling, "granulating into star-dust," in the process of transition from nebulæ to suns.

Foremost among the worlds comparable with our planet, when in the condition of igneous fluidity, is the centre of our own solar system. Though fourteen hundred million times larger than the earth, the sun possesses only one-fourth the density of our world, being a trifle heavier than water. The hourly radiation of heat from each square foot of his surface is equal to the combustion of 130,000 pounds of bituminous coal. This is abundantly adequate to heat and illuminate all bodies in space within hundreds of millions of miles from his surface. Suns like this are to be enumerated by the thousand in the heavens, all of them doubtless the centres of other star-systems, imparting light and heat to numberless planets.

It is less easy to determine the character of worlds in the former condition of ours, just incrusted after igneous fluidity, no longer a sun, but shining by borrowed light reflected from some greater sphere, because they are wrapped in an opaque envelope. The moon, whose proximity enables us to inspect her hills, craters, and valleys, appears to have been thoroughly cooled from fusion. She is solid to the core, and has approximated to that final period of barren desolation not yet attained by the earth. Most of the outer planets, Jupiter, Saturn,

FIG. 3.



TRANSITION FROM THE SPIRAL TO THE ANNULAR FORM.

Uranus, and Neptune, have a small specific gravity; but we cannot tell whether they have advanced beyond us in the cycle of progress, or whether they are yet immature. The adjacent planets, Venus and

Mars, may be more like the earth, and fitted to support animal and vegetable life. If not inhabited by human beings, they may be passing through their preliminary Paleozoic, Mesozoic, or Cenozoic stages. And there are, probably, though their names are unknown to us, in the distant regions of space, deriving light and heat from suns seeming mere points to us, worlds where the early Eozoön rears its calcareous reefs, the gigantic Labyrinthodon croaks amid the primeval quagmires, and the Connecticut birds are leaving upon the marine mud the imprints of their tridactyle feet. Nor is it unlikely that other species of men inhabit some of these scattering orbs, and are as curious about us and our institutions as we are about them.

THE NEBULOUS PERIOD.—The usual geological argument for nebulosity is derived from the attempt to understand the origin of the condition of igneous fluidity. If the earth has been cooling from fusion, perhaps this is a cooler condition than the still earlier hotter state of fiery gas. Solids expand into liquids when heated, and liquids may become gases for the same reason. This gas, however, may not necessarily have been hotter than when condensed. The particles of matter must be the same when volatilized, as in both the liquid and solid states. Every substance now existing beneath the atmosphere must have been present—the compact ledges of the firmly-seated hills—the stone-walls of ancient cities—the water of the ocean—the oily fluid spouting from the bore-holes of Western Pennsylvania—the very particles of the paper containing this sentence printed upon it—and even the elemental constituents of our bodies, so fearfully and wonderfully made—all these and every thing material may have been commingled with the atmosphere, hovering about in a vaporous form, the components of a nebula, or comet.

In the attempt to surmise the actual condition of the elements at the beginning of the nebulous period, two views may be held, according as we prefer to adopt a chemical or mechanical theory of their origin. If one does not care to imagine the atoms called into existence in a heated condition, he may suppose that matter first appeared with the common frigid temperature of space, or about one hundred degrees Fahrenheit below the freezing-point of water, and that the elements were uncombined. Newly born, these particles would immediately commence to display their affinities, and the result would be explosive combinations, giving off intense light and heat. The latter force permeating the elements, would soon reduce them, first to igneous fluidity, and then into heated vapors. Every atom flying away from every other one, on the principle of "dissociation," would give rise to a nebula of enormous dimensions in a comparatively short time from these cosmic materials. After the formation of the nebula, the series of changes about to be described would commence its rounds.

A mechanical theory is presented by the distinguished philosopher, Dr. J. R. Mayer, author of a treatise upon "Celestial Dynamics."

He assumes that our globe was once very much smaller than it is at present, and that independent masses of matter, perhaps other planets, have fallen upon it, the shock of collision generating an enormous degree of heat. This is an effect of the "crush of worlds" not commonly apprehended. If two bodies, conjointly equal to the bulk of the earth, were rapidly traveling through space, and should violently come together, their collision would evolve enough heat to convert the united mass into lava, or heated vapor. An asteroid falling upon the sun would generate from 4,600 to 9,200 times as much heat as would come from the combustion of an equal mass of bituminous coal, the force of velocity changing into caloric. This view, though adequate to explain the origin of the nebula, does not account for the existence of the colliding bodies. It might be consistent with the doctrine of the eternity of matter, in which case the colliding planets may have been coursing about the sun for myriads of ages as aggregations of matter corresponding to the last term of the great cosmic cycle—inorganic sterility. Could we understand how all the planets might eventually fall into the sun, we might suppose the present series of changes is only one of several cycles, in agreement with the speculations of certain writers.

Dr. Mayer carries his theory much farther. He does not confine these cataclysmic unions to the ante-nebulous periods. It is suggested that there may have been similar accretions to the surface of our planet after the introduction of life. A luxuriant vegetation, or a thickly-peopled continent, may have been often buried beneath the fiery *débris* resulting from the conflict. There are frequent occurrences of a similar character at the present day, but of trifling influence upon the general temperature. Every solid meteor that falls from the sky develops heat; and it cannot be denied that, were these bodies of large size, the calamitous occurrences depicted by Dr. Mayer would be experienced. Each one of these cataclysms would interrupt the cycle of progress as set forth above, and carry the order of the mutations back to the beginning.

When we study the scheme of worlds revolving around the sun, we discover that they all rotate on their axes in the same direction; that they all proceed from west to east, their orbits being nearly circular, and in almost the same plane, which is nearly coincident with that of the sun; that the sun moves on his axis in less time than any of the planets, and each planet rotates more quickly than its satellite. These and other facts point out a community of origin and development inexplicable by chance or the law of gravitation. We suppose, then, that the sun and all the planets and their satellites composed originally a single mass of luminous fog, with a diameter exceeding that of the orbit of Neptune, the remotest planet, or not less than three thousand million miles. This would correspond well with the supposed dimensions of the smaller nebulæ now seen in the skies. The

history of the earth at this early period was, therefore, merged in that of the solar system.

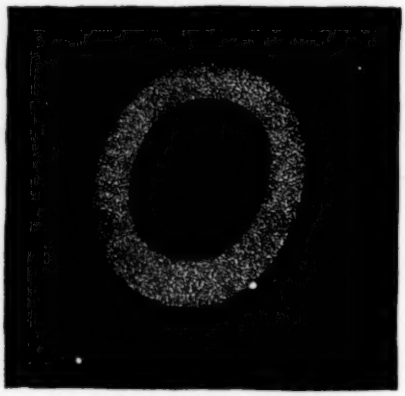
The centrifugal force produced by rotation would cause rings of gaseous matter to separate themselves one after another from the central mass, the latter turning on its axis more rapidly after the removal of the exterior. The separated ring would then have been an annular nebula. As many as six rings must have been cooled before the earth-mass separated itself from the interior sphere carrying the substance of the sun, and the inferior planets.

The next stage of growth would naturally consist in the breaking up of each ring by itself, perhaps in consequence of inequalities in different parts, and condensation into a sphere of greater specific gravity. The falling of the particles would add heat, and perhaps quickly induce the fluidity of the mass. While still gaseous, other rings may fly off, to become satellites. All the nebulæ, by constant rotation, may have given freedom to the contained particles to arrange themselves according to their relative densities, the heaviest atoms falling to the centre, and the lightest remaining at the surface. The process of separation into zones must have been analogous to the cooling of liquids. As fast as their superior density caused particles to descend, the lighter atoms would be displaced and sent to the surface, either to be cooled, or to remain permanently in a higher stratum. But, at the close of this period, there must have been, outside of the fluid, an enormous thickness of gases which did not liquefy till after the crust had formed to a considerable amount.

Period of Igneous Fluidity.—At the commencement of this period the earth seems to have been a flattened sphere, composed of melted matter like lava, encircled by steam and easily-volatilized liquids and solids, but girdled externally by an atmosphere; rotating upon its axis and revolving round the central sun. It was a sun of itself, emitting light and heat, thus forbidding the distinction of day and night, though the planetary movements inducing the alternations of position were as well marked as now. The several compounds constituting the material of the earth were probably arranged in concentric zones according to their relative gravities, just as we now observe the settlings in a copper or iron furnace. A general mixture of rich and poor ores, fluxes and fuel, is put into the receiving-vault; when ignited, the solids mix together, melt into a fluid, the heavier metals sinking to the bottom, and the slags rising to the surface to be skimmed off. So the metals would naturally gravitate to the centre of the fluid earth, and around them might be several zones of successively lighter compounds, the exterior being the least heavy of all, and answering to the slags of the furnace. The specific gravity of the whole earth is now 5.65, when compared with water, as determined from astronomical sources; but that of the surface-rocks is less than half this amount: hence we have abundant reason to believe that the

same general relation of light and heavy zones still exists, and that the deeper we descend the more abundant the proportion of the denser metals. The germ of this arrangement was undoubtedly induced in the nebulous age. The compression of the surface-elements into a quarter or half their known bulk cannot explain the great weight of the interior, for experiments indicate that a limit to the capacity of reduction of volume is soon reached. So far as we know, the reduction of bulk by pressure becomes less and less in proportion to the pressure exerted.

FIG. 4.

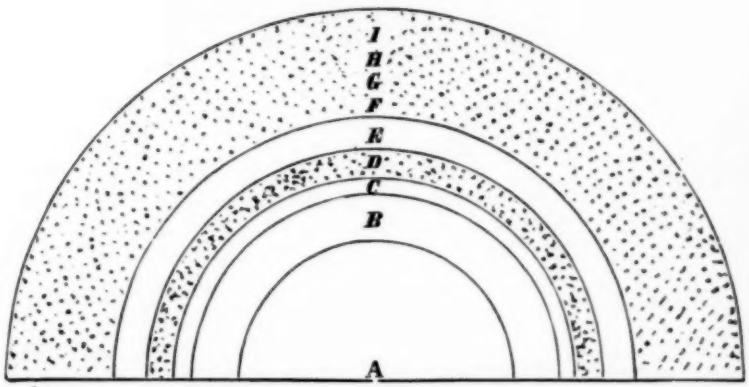


ANNULAR NEBULA IN LYRA.

Some interesting observations have recently been made by Prof. Daubrée, of Paris, upon the analogy between certain terrestrial rocks and the heavy meteoric stones which occasionally fall from the sky. Some of the meteorites are nearly pure iron; others either contain grains of minerals like olivine, or consist chiefly of the olivine, with only occasional particles of iron. This latter class are silicates of magnesia and the protoxide of iron, allied to the minerals olivine or peridote, and a granular compound of anorthite and pyroxene. Patrin, so long ago as 1809, called the attention of observers to the identity between the composition of certain meteors and substances ejected from volcanoes; and, in 1858, Von Reichenbach sketched theoretically some of the conclusions just arrived at experimentally by Daubrée. Reichenbach showed that most of the mineral species found in meteors existed also in the trap called dolerite; hence he inferred that masses of material allied to the stony meteors are located deep down under the volcanoes whence the lava was derived. Daubrée has manufactured in the furnace masses apparently identical, both with the metallic and stony meteors. The latter were most successfully imitated by melting down the mineral compounds peridote, Cherzolite, hypersthene, basalt, and melaphyre. Allied to them is the dumite of New Zealand, an aggregate of olivine and chromite.

The Cherzolite, a volcanic aggregate of peridote, enstatite, and pyroxene, from the Pyrenees, in Spain, presented, after fusion, specimens the most like the meteorites. These experiments suggest that the meteors had once been fused, as is commonly believed, and that the slight differences existing between them and the peridotic rocks may be explained by supposing the latter to have cooled in the presence of oxygen (or air), while the former may have solidified where the supply of oxygen was limited. When melted, the two mixtures are precisely alike, and we may conceive of the existence beneath us, in the great caldron whence the volcanoes derive their lava, of a zone of meteor-like mixtures, both the peridotes which are now melted and occasionally brought to the surface, and the heavier metallic masses, too deeply seated to be ejected by any convulsive throb of our planet. For aught we can say, the heavier meteors may indicate the exact character of the interior nucleus, just as those black stones falling from the sky have revealed the composition of other worlds. Their weight would correspond well with that of the interior mass. The specific gravity of granite is from 2.64 to 2.76; of basalt, 2.9 to 3.1; the peridotes, 3.3 to 3.44; and the heavy meteors from 7 to 8. Hence, while the granitic

FIG. 5.



ZONES IN THE EARTH AND ATMOSPHERE.

A. Solid Nucleus of Heavy Metals or Meteors; B. Region of Stony Meteors; C. Region of Lava; D. Region of Basalt and Pophyry; E. Region of Granite, and Surface of the Solid Crust; F. Region of Acid Gases; G. Region of Carbonic Acid; H. Region of Nitrogen and Oxygen; I. Steam.

materials may have cooled near the surface, and the basalts lower down, the stony meteors would form a zone beneath the second, and the metallic masses, if present, may constitute the central nucleus. We must not forget the trachytes, and most modern lavas, which would underlie the basalts. It would be easy to calculate the thickness required for these different zones, whose general average should be the density of the earth. When water is added to the peridotes and stone-meteorites, the rock is analogous to serpentine. We may

remark that the crust abounds most in the oxides of those metals which have the strongest affinity for oxygen, as the alkalies and alkaline earths; while in the peridotic and lower zones the proportion of these elements is much less, and that of the earths and metals is much greater. The minerals composing the superficial crystalline rocks, as well as water, are generally absent from the meteorites. This is especially noticed in respect to the mineral quartz or silica, so common at the surface. According to these views, the granites must once have been in a melted condition, and the excess of silica present in them have assumed the amorphous form. Many geologists have supposed the silica ought to have crystallized first, if the rock cooled from fusion. It may be that our ideas of the intense heat have been exaggerated; yet the Labrador granites of New Hampshire have recently been shown by us to be situated in sheets over a plain, precisely like the erupted lava of the present day.

We have dwelt upon the present concentric structure of the earth, because it was probably the same with that existing in the igneous period, at that time fused, but now largely solid. The order of the alternations has always been the same. It corresponds also with that observed in furnaces, where the metal sinks to the bottom, and is overlaid by one or more successive layers of slag.

This complex sphere, when molten, with its fiery billows and igneous currents, being situated in a fearfully cold region, could not fail to radiate heat; and, like other melted bodies, become covered with a congealed crust. A pot of melted iron taken out of the fire loses heat, and a crust speedily forms over it, shrinking as it cools; and, if the exterior be broken, the red liquid may be poured out. The same thing may be seen on the dumping-heaps connected with melting-works. Masses of slag, with their entire surface congealed, are placed upon the car and wheeled to the end of the pile; but, when thrown down the slope, they are fractured, and the liquid interior flows out like water. When a stream of lava flows down a slope, the surface and sides of the molten river are soon covered by a thick crust, the result of cooling. This will become so firm that men may walk upon it, as upon ice over lakes in the winter. During one of the eruptions from Vesuvius, when lava covered the town of Resina—the old Herculaneum—some of the inhabitants, driven to the tops of the houses, escaped by walking over the stiffened crust, before the flow had ceased. Whenever the lateral walls of the stream are broken, the lava will flow out and change its course. In this way, a current threatening to engulf a village may be averted and directed elsewhere. This is a practical matter, and has been turned to account in Sicily, in warding off from Catania the threatened calamity rolling down the slopes of Etna.

Our entire experience, therefore, of analogous phenomena, leads us to believe that a crust will be formed, and that the several zones will cool in natural order in later periods. Not till the last melted layer

between the crust and solid nucleus has solidified, will eruptions of lava cease to flow from volcanoes.

As time progressed this congealed crust would increase in thickness. Being unyielding, there would be stamped upon it, as plainly as the form of a pitcher by the moulder, the peculiar flattening of the earth, as determined by the rate of rotation. As soon as the internal fires were concealed, the rotation of the earth would give rise to the alternation of day and night—not, certainly, of the same length as now, since the bulk of the sphere was greater, and with a reduction of size the tendency is to an increase in the rate of rotation. But, with the thick atmosphere, the days must have been dark and gloomy.

At the present day the attraction of the sun and moon produces the phenomena of the tides. As the crust is rigid, only the water upon it can now be moulded into different shapes. But, when the whole earth was pliable, its form must have varied daily, much more symmetrically than at present. As the outer envelope stiffened by cooling, tidal waves would form with great difficulty, and eventually the crust would become too rigid to be affected. Perfect rigidity was not attained during the whole inorganic period. While thin, the crust may have been broken by the attraction, and the liquid oozed out through the crevices, overflowing the surface, and returning at low tide. So great is the power of tidal attraction that a rigid envelope, hundreds of miles in thickness, would be fractured by it. The rents formed were like the faults observed in the strata of the organic periods. More or less fracture probably attended every tidal attraction, until the ocean covered the surface, and presented a material easily modulated.

Age of Chemical Changes.—Following the age of igneous fluidity there succeeded another of great interest. It opens with the surface dry, rough, and slaggy; the interior in intense fusion, and the atmosphere containing all the water of the ocean with numerous volatile compounds. Before its close an ocean is formed, most of the gases have left the atmosphere, and chemical agencies acted with great intensity, and so universally as to characterize the period. The falling of the primeval rain dissolved acids in the air, and poured upon the elements never exposed to moisture streams of acidulous waters, well fitted to dissolve out large portions of the original crust.

In order to ascertain the character of this primitive rock, we must adopt the method suggested by Sterry Hunt, in his lecture before the Royal Institution of Great Britain, and consider what changes would result if intense heat should now act upon the crust. The water everywhere would be evaporated, leaving behind its saline impurities. All the carbon in living plants, and the immense supplies of coal stored up in the earth, would become converted into carbonic acid; the siliceous parts, fused with limestones and other rocks, would make silicates of lime, magnesia, etc., and expel the carbonic acid. The sulphur would form sulphurous acid with oxygen, changing eventually

into sulphuric acid as the temperature moderated. Inasmuch as sea-salt, water and silica, when heated together in a confined space, form hydrochloric acid and sodium silicate, it is probable that in these early times the saline residues were decomposed, and the chlorine set free to combine with the hydrogen, and thus manufacture hydrochloric acid on a large scale. The solid bases, therefore—lime, magnesia, soda, potash, and the metals—would be combined into a great slag, and various minerals would crystallize out from it while cooling. By loss of heat the slag would contract irregularly, and there would be inequalities upon the surface, hills and valleys without system or order.

Some authors think the salt would be volatilized, and form a zone at the base of the atmosphere. The papers of Hunt, Forbes, Wurtz, Winchell, and others, show that authors cannot yet agree upon the details of those wonderful changes. The sources of our information are meagre, and the opportunity for diverse views is easy, where such immense periods of time are concerned, so that this discordance is not strange. We cannot regard Dr. Hunt's illustration as perfect, since the earth may never have been a fused mass of equal density throughout, the concentric zones having been essentially segregated in the nebulous period.

The atmosphere may possibly have been arranged in zones. Containing the present gases encircling the crust, the carbonic acid derived from coal and the carbonates, the sulphurous and hydrochloric acids, water converted into steam, and possibly volatilizable compounds, it would constitute an atmosphere of extraordinary density and insalubrity, perhaps six or seven times heavier than at present. We may suppose that the law of diffusion of gases is subordinate to that of gravitation; whence there would result four zones, viz., sulphuric and hydrochloric acids at the base, surmounted first by carbonic acid, and then by a mixture of nitrogen and oxygen; and, lastly, by steam. This dense gaseous covering would prevent much of the radiation of heat from the earth, and produce a universal tropical climate.

As the steam lies nearest the cooling influences of space, it would be the first to be affected by radiation. Drops of water would aggregate and descend, which would be vaporized again explosively, when brought in contact with hot surfaces. The cooling influence increasing its power, the number of falling drops increases, but they continuously return to the outer envelope, till the crust is sufficiently thick and cool to retain them. Thus, at the beginning of this age, there was a terrible conflict between the clouds and the earth, the former pouring down streams of water, which the latter refuse to receive; but the clouds eventually gain the mastery, and the earth sullenly evolves simmering masses of vapor from a hot-water bath.

Imagine, now, the earth capable of holding the falling drops. The water will descend in torrents, for there is to be a transference of the entire ocean from the upper atmospheric zone to the solid earth, where it

properly belongs; the waters above are to be separated by the "firmament" from the seas beneath. Next, we may observe chemical reactions. The condensed steam, in falling through the lower zones, would dissolve the sulphuric and hydrochloric gases, and convert the rain into powerful acids. When these fall upon the slaggy crust, the excrescences will not only be removed, to be deposited as sediment in the hollows, but a large percentage of the surface will enter into solution, giving rise, not to an acid ocean, but one containing sulphates and chlorides. The more soluble silicates would be converted into chlorides, leaving upon the slaggy floor piles of silica. The sulphates may have been largely of the heavier metals, not excluding the others.

FIG. 6.

PRIMEVAL RAIN.

Prof. Wurtz thinks the first ocean would be characterized by the predominance of sulphates. Granting this, we can understand the conversion of the sulphates into sulphurets in subsequent periods, as well as into gypsum. Aqueous deposits of sulphurets of copper, iron, lead, antimony, etc., are common in Eozoic and Paleozoic strata. The action of carbonic acid must not be overlooked. The liquid acids may have disintegrated the silicates of the alkalies and alkaline earths; but the compounds of silica, with alumina and iron, are not so easily decomposed. As soon as the carbonic acid could act upon feldspar compounds, we should have the potash and soda dissolved out as carbon-

ates, leaving behind heaps of kaolin clays, such as now form, for the same reason, from the decomposition of granite. This reaction is one peculiar to dry land, and would therefore be subsequent in time to the changes already mentioned. Now, the potassium and sodium carbonates, when brought into contact with calcium chlorides, change their composition, and there result calcium carbonates and sodium and potassium chlorides. These carbonates, being insoluble, will be precipitated to the bottom, and thus will be formed the primitive travertines and limestones, while the sodium chlorides remain in solution to this day, save what has been converted into beds of rock-salt.

With the removal of the bulk of the acids and possible volatile compounds from the atmosphere, only carbonic acid would remain to render it impure at the close of the era of chemical changes. In later periods this part of the atmosphere has also been removed. The world is not yet ready for life, as there must be further chemical and mechanical changes.

THE FORMATION OF SEDIMENTS.—The next era brings into play a phase of action destined to be the chief agent of change in the world—the erosion of existing ledges to form new rocks. The era opens with a continuation of the atmospheric decompositions, whereby we find silica and alumina remaining in irregular heaps of sand and clay, and the accumulation of calcareous deposits beneath the ocean.

The formation of thick deposits of inorganic limestone is extremely interesting. Scientists have been wont to ignore altogether the existence of any deposit of this character, since microscopic researches into the structure of many of the calcareous masses exposed at the surface indicate an organic origin. So many shells and coral fragments aid in building up fossiliferous limestone that its mode of growth is very clear. But, after one has spent months in searching vainly for traces of organisms among the marble layers of Western Vermont, or the auroral limestones of Eastern Pennsylvania, he is tempted to suspect that some of the Silurian limestones even were chemical deposits, though wanting the concentric structure of stalagmite and travertine. But, barring these, and the calcareous dikes in the Laurentian of Northern New York, and in the Silurian beds of Northern Vermont, all the phenomena are best explained by the presence of an inorganic limestone before the origin of life. Whence came the materials for the stony habitations of marine animals? There must have existed great masses of the crude material, stored up in the rocks and in the waters of the sea, to provide with coverings all the testacea of every age, and to furnish the thousands of feet thickness of the Eozoic, Paleozoic, and Mesozoic limestones. This primitive source of supply is now concealed, but much of its material has been used over and over again.

We have suggested how three of the principal rock-materials have been formed—the quartz, clay, and limestone. We have them yet as rude piles of rubbish, neither arranged in layers nor possessing any

determinate form. Next comes the history of the processes by which system is induced. There were hollows and valleys in those early times, most probably vast and deep, but not irregular. The constant fall of rain must originate brooks and streams, coursing their downward way toward the lowest levels. Animated with this descending impulse, they remove barriers at the outlets of lakes and pools, excavate gorges through ridges of impediment, and wear off numerous fragments from every projecting point. This eroded material would be urged forward by the current till the lowest possible level was reached, probably the bottom of an arm of the sea or bay, and remain there while the basin was filling up. Thus we should have a *formation*, composed of layers of the sand, clay, and limestone, originally a chemical precipitate, but now altered into sedimentary deposits. When the first accessible hollows had been filled up, a great interval of time had elapsed, and the external envelope of the earth would shrink, on account of its refrigeration, and fall upon the collapsed nucleus. Hence new valleys would be formed, and the streams would carry the detritus into them, and another set of strata lying upon the edges of the first formation would be deposited. This process has been going on uninterruptedly from that day to the present, and the face of the earth has been changed a hundred times. How long this process went on before the introduction of life it is impossible to say, for the oldest strata known to exist contain the remains of the Eozoic reef-building colonies, in the formations known as the Laurentian.

As some of the older Laurentian beds are composed of pebbles, it is obvious that earlier formations exist, from which the sedimentary material has been derived. Possibly we may be able ultimately to separate from the various systems of the age under consideration those characterized by the presence of the first existing plants—since in the order of Nature there must have been plants before animals. If we follow the analogy of the duration of the earlier periods, we may believe that this *Eophytic* age exceeded the Eozoic in length; and, furthermore, that the time before the introduction of life was far greater than what has lapsed subsequently. If the law admits of universal application, that the simpler the organism the longer it has lived, then we may perhaps claim that the earlier the period the greater has been its duration. The extent of work performed in these early ages has certainly far exceeded any thing yet known of the operations in the Zoic periods.

The series of changes prior to the introduction of life may therefore be registered as distinct ages, as well marked by special features and a natural order of succession as the periods defined by Paleontology. The minute details of the history are wanting, but, with such substantial bases of probability as have been set forth, human thought will construct theoretical systems that will command universal acceptance.

As now understood, the following titles may express the characteristic features of all the great ages of the world, from the birth of matter to the advent of man:

MATTER CONVERTED INTO VAPORS.
NEBULA COMPOSED OF THE ENTIRE SOLAR SYSTEM.
THE EARTH-NEBULA.
PERIOD OF IGNEOUS FLUIDITY.
AGE OF CHEMICAL CHANGES.
BEGINNING OF THE SEDIMENTARY PERIOD.
INTRODUCTION OF VEGETATION; or, Eophytic Period.
INTRODUCTION OF ANIMAL LIFE; or, Eozoic Period.
PALEOZOIC ERA.
MESOZOIC ERA.
CENOZOIC ERA, COMPLETED BY THE ADVENT OF MAN.

WALKING, SWIMMING, AND FLYING.

BY E. LEWIS, JR.

THROUGHOUT the realms of Nature motion is indispensable to physical stability and organic existence. It is everywhere present, and equally among molecules and masses the mind searches in vain for evidence of absolute rest. It has been declared that "organic life is a result of motion;" certain it is that motion is a condition of life. It appears in the endless manifestations of beauty and utility, in the world of living creatures of which ourselves are a part. The heavens are more beautiful when clouds are drifting, and the motions of animals give a charm to a landscape which disappears in the solitude of a desert. Stillness to the eye, like silence to the ear, becomes at last painfully oppressive. We scarcely realize, perhaps we seldom consider, how much of the joy and value of existence depends upon the movement of beings, and the marvelous perfection of the means by which it is effected. Walking, swimming, and flying, are the means by which we traverse the three great highways of Nature—the land, the water, and the air. If we change our position, it is in one or other of these. There is no more fascinating chapter of science than this. The mere fact of animal locomotion is felt to be an expression of beneficence, and of adaptation of means to ends which surpasses human ingenuity.

What laws of motion are revealed, what principles of mechanics are brought into action, when animals walk, swim, or fly, has been discussed by many writers, but by none in a more able or interesting manner than by Dr. Pettigrew, who, in a volume soon to appear in

the International Series, has given the results of a long course of observations and study upon the subject.[1]

The three modes of progression, apparently so unlike, are nevertheless essentially the same. The limbs of the quadruped, the wings of the bird, and the fins of the fish, are built upon the same general plan of structure, and are applied fundamentally to the same uses. They are traveling surfaces, and their wide range of modification is in direct relation to the media in which they are used. The one treads the solid ground, another the water, and another the yielding and elastic air. "But walking merges into swimming, and swimming into flying, by insensible gradations; and these modifications result from the fact that the earth affords a greater amount of support than the water, and the water than the air."

Most terrestrial quadrupeds can swim as well as walk, and some can fly. Many marine animals both walk and swim, and birds and insects walk, fly, and swim, indiscriminately. It is not surprising, therefore, that, between the typical foot, wing, and fin, innumerable modifications in structure and form occur; indeed, so graduated are they that it may be difficult to determine where one form ends and another begins.

In Fig. 1 we have several illustrations of the traveling surfaces of

FIG. 1.

A. B. C. D. E.

A—Extreme form of compressed foot, as seen in the deer, ox, etc., adapted specially for land transit.
B—Extreme form of expanded foot, as seen in the ornithorhynchus, etc., adapted more particularly for swimming.
C—Intermediate form of foot, as seen in the otter.
D—Foot of frog. Here the foot is equally serviceable in and out of the water.
E—Foot of the seal, which opens and closes in the act of natation.

animals. The small feet of the quadruped, the webbed feet of the ornithorhynchus, the otter, the walrus, and the triton, indicate with certainty the media to which they are adapted, and perhaps in nothing is modification of structure and form to habits more apparent than in the locomotive appendages of animals. The webbed structure between the toes of animals which live partially on the land, and of some terrestrial animals, as the water-dog, is wonderfully significant.

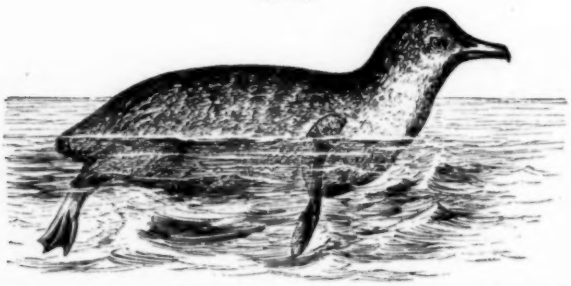
The wing of the penguin, Fig. 2, is scarcely more than a flipper, and the same is true of the auk.

Sir John Lubbock describes a species of insect whose wings are

[1] "Animal Locomotion; or, Walking, Swimming, and Flying." By J. Bell Pettigrew, F. R. S. International Scientific Series. New York: D. Appleton & Co.

used as fins only. "Every variety of motion peculiar to land, air, and water-navigating animals, as such, is imitated by others which take to the elements in question, secondarily or at intervals." It is probably true, however, that no animal which lives indiscriminately in two media attains the highest development for traveling in or upon either. In such cases the maximum speed is not attained. Those animals, says the author, which swim the best, walk, as a rule, with difficulty, and *vice versa*, as the movements of the auk and the seal, in and out of water, amply testify. It is evident that all the supposed gaps between typical forms for locomotion are bridged by forms intermediate, and the author's position is fully sustained, that walking, swimming, and flying, are essentially the same.

FIG. 2.



THE LITTLE PENGUIN, adapted exclusively for swimming and diving. In this quaint bird the wing forms a perfect screw, and is employed as such in swimming and diving.

Before entering upon the question of the movement and functions of specialized organs for locomotion, attention is invited to the interesting statement that, however wonderful and beautiful, in its way, the bony skeleton may be, it is after all only an adjunct to locomotion, and of motion in general—that all the really essential movements of an animal occur in the soft parts. "The osseous system is therefore to be regarded as secondary in importance to the muscular, of which it may be considered a differentiation. Instead of regarding the muscles as adapted to the bones, the bones ought to be regarded as adapted to the muscles. Bones have no power either of originating or perpetuating motion. This begins and terminates in the muscles."

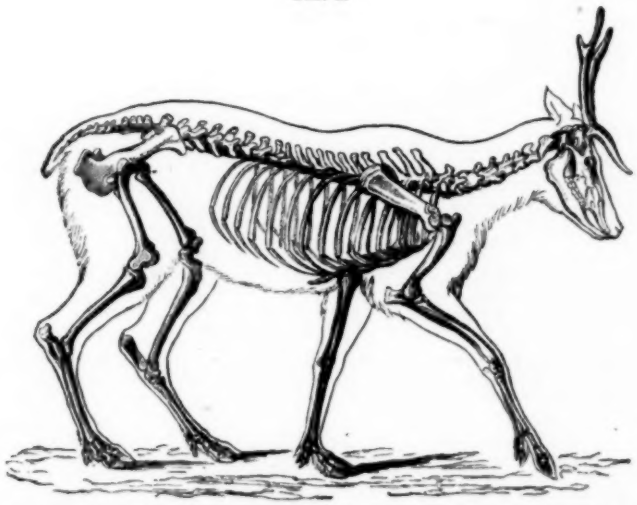
The bones are the passive organs of locomotion, in the movement of which muscular force is expended. In land animals, as a rule, the bones are harder and more elastic than in aquatic species. The cartilaginous and spongy bones of many fishes would be ill suited to bear the strains and shocks of terrestrial progression.

The velocity with which a limb may be moved will depend upon the acuteness of the angles of its several bones. Hence the fleetness of many animals, in which the angles formed by the bones are acute. This is well shown in the skeleton of a deer, of which Fig. 3 is an ex-

cellent illustration. Here we have not only the sharp angles, but lever-like adjustment of the several bones.

From these arises the power possessed by many animals to bound or leap enormous distances. The kangaroo has been known to leap twenty feet. The jerboa, when pursued, will pass over nine feet at a bound, and repeats so rapidly that a swift horse can scarcely overtake it. The greyhound and the hare will pass over sixteen feet at a stride. Animals of great weight and moderate speed have nearly straight limbs. Those of the deer are more angular than those of a horse, and those in the wing of a bird more angular than those of the fleetest quadruped.

FIG. 3.



SKELETON OF THE DEER (after Pander and d'Alton). The bones in the extremities of this, the fleetest of quadrupeds, are inclined very obliquely toward each other, and toward the scapular and iliac bones. This arrangement increases the leverage of the muscular system, and confers great rapidity on the moving parts. It augments elasticity, diminishes shock, and indirectly begets continuity of movement.

The forms of joints which predominate in the animal kingdom are the hinge and the ball and socket. The latter gives to the extremities their extraordinary range of motion, and a power of rotation so indispensable, as we will see, to the effectiveness of all the organs of locomotion.

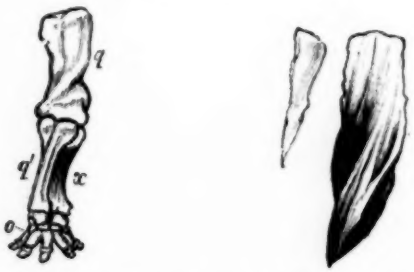
It has been shown that a spiral configuration occurs in the bones and joints of the wing of the bat and the bird, and in the extremities of most quadrupeds. "The bones of animals are, as a rule, twisted levers, and act after the manner of screws." Thus it is that their traveling surfaces in progression may be turned at almost any angle, getting from the resisting media in which they move as much propelling power as possible, with a minimum of slip or waste.

It is because the traveling surfaces of animals "are screws struct-

urally and functionally" that they can seize and let go the fulcra on which they act; particularly is this the case in the water and in the air, the form and movement being such that the greatest results are secured with the least expenditure of force. The muscles cover the bones, in layers or strata, and run longitudinally with them, and with each other, but also at every degree of obliquity. The spiral structure and movement of bones of animals have been carefully analyzed by Dr. Pettigrew, and some of his conclusions are illustrated in Fig. 4.

FIG. 4.

WING OF BIRD.—Shows how the bones of the arm (*a*), forearm (*b*), and hand (*c*), are twisted, and form a conical screw.



ANTERIOR EXTREMITY OF ELEPHANT.—Shows how the bones of the arm (*q*), forearm (*q'x*), and (*o*), are twisted to form an osseous screw. Cast or mould of the interior of the left ventricle of the heart of a deer. Shows that the left ventricular cavity is conical and spiral in its nature.

The *voluntary* muscles of the wing, he finds, are upon the same pattern as are those of the *involuntary* muscles of the heart. He compared the bones removed from the forelimb of a quadruped or bird, with a cast obtained from the cavity of a hollow muscle, the left ventricle of the heart of a mammal, and found that the bones and the cast are twisted upon themselves, and form elegant screws, the threads of which run in the same direction.

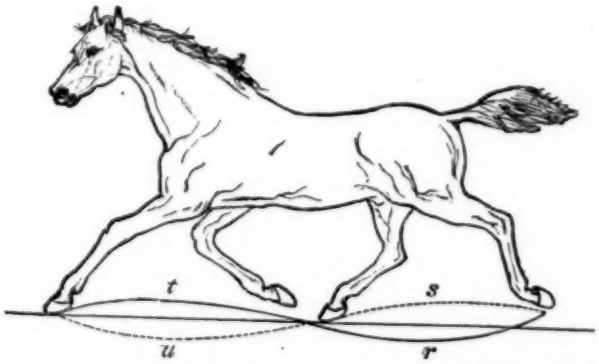
FIG. 5.

Diagram, showing the figure-of-8 or double-waved track produced by the alternating of the extremities in man in walking and running.

The movement of the limbs of a quadruped is in curves, which, continued, form a figure-of-8, or a series of them; a fact in progression first pointed out by Dr. Pettigrew. Quadrupeds, says the author, walk; fishes swim; insects, bats, and birds, fly by figure-of-8 move-

ments; and, in human locomotion, the same phenomenon is observed. The diagram, Fig. 5, shows the curved track made by man walking. The accuracy of this is easily verified by observation. As the limbs swing forward, they move in the arc of an ellipse; that is, in a slight curve outward, and with the arms form the double curves, as shown in the figure. In the movement of the horse, walking or trotting, the same phenomenon appears, as the figure shows.

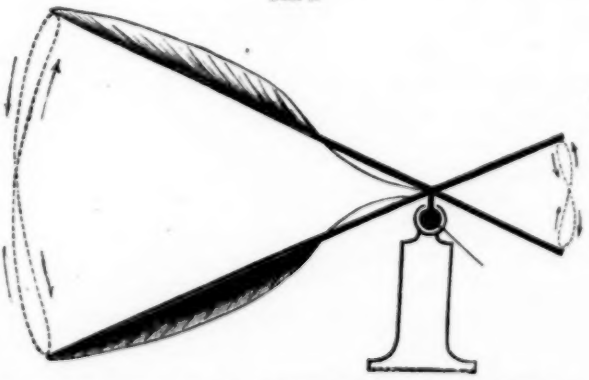
FIG. 6.



HORSE IN THE ACT OF TROTTING.—In this, as in all the other paces, the body of the horse is levered forward by a diagonal twisting of the trunk and extremities, the extremities describing a figure-of-8 track (*s*, *u*, *r*, *t*).

The wings of birds, bats, and insects, describe similar curves. They are produced by the rotation of the wing, as it rises and falls, so that it twists, screw-like, on its long axis, one-half of the figure being formed in the ascent, the other in the descent of the wing.

FIG. 7.



IMITATION OF WING MOVEMENT BY A REED WITH FLEXIBLE SAIL MOVING ON A BALL-AND-SOCKET JOINT, SHOWING THE DOUBLE CURVES.

The double curves or figure-of-8 lines which thus occur are not mere coincidences, nor in any sense accidental, but the expression of a

law of movement of vertebrated animals, and, from a most extended series of observations, Dr. Pettigrew concludes:

"That quadrupeds walk, and fishes swim, and insects, bats, and birds fly, by figure-of-8 movements.

"That the flipper of the sea-bear, the swimming wing of the penguin, and the wing of the insect, bat, and bird, are screws *structurally*, and resemble the blade of an ordinary screw-propeller.

"That those organs are screws *functionally*, from their twisting and untwisting, and from their rotating in the direction of their length, when they are made to oscillate.

"That they have a reciprocating action, and reverse their planes more or less completely at every stroke.

"That the wing describes *a figure-of*-8 *track* in space when the flying animal is artificially fixed.

"That the wing, when the flying animal is progressing at a high rate of speed in an horizontal direction, describes a *looped* and then a *wave* track, from the fact that the figure-of-8 is gradually *opened out and unraveled as the animal advances.*"

He constructed artificial fish-tails, fins, flippers, and wings—flexible and elastic—slightly twisted upon themselves, and applied them respectively to the water and air by a sculling or figure-of-8 motion. The curved surfaces and movements peculiar to the living organs were reproduced. The purely mechanical movement shown in this application of traveling structures to their environment scarcely admits of doubt.

Man is enabled to travel in two of the three great highways of Nature. He can progress upon the land, swim in the water, but fly he cannot; nor has he yet invented a means by which flying is possible. By his applications of natural laws he has "outraced the quadruped on the land and the fish in the sea," and the conclusion from the analogy and nature of things is, that the "tramways of the air will yet be traversed by man's ingenuity."

A balloon floats, it does not fly. It floats because it is *lighter* than the air; a bird is enabled to fly because it is *heavier* than the air, and weight is an important element in all, but especially in aërial and land locomotion. It is that by which the extremities of animals seize and hold their position in the media in which they move. If a man were no heavier than the air, the movement of his limbs would avail him nothing. The earth is his fulcrum, as the air is that of the bird, and water that of the fish. Progression, therefore, implies gravity and the power of resistance, which gravity affords. A body which floats is carried along with the media in which it is; having lost its weight, it has lost its power of self-control. A man who cannot swim is at the mercy of the slightest current or wave, if in depth at which the lifting power of the water makes his foothold insecure.

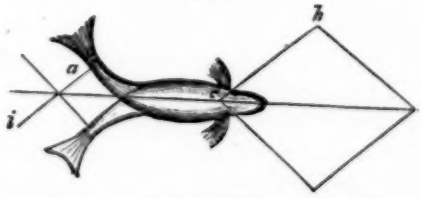
A man standing still commences to progress by throwing his body

slightly forward. Some momentum is thus obtained, the limb being simultaneously advanced. "The throwing forward of the body may be said to inaugurate the movement of walking." The same occurs with a horse, but, if attached to a load, great impetus is attained by the body before either of the limbs is lifted. Momentum thus relieves muscular strain in the limbs and economizes force. How completely this principle is applied in swimming and flying will be presently noticed.

In ordinary walking of man or quadruped, the limbs swing forward without muscular effort. According to Prof. Weber, they swing by the force of gravity as a pendulum, and obey the same laws. If suspended they oscillate freely, and gravity brings them to a position of rest. How much the muscles are saved from exhaustion in ordinary locomotion, by gravity, becomes obvious when we attempt to overcome it by climbing or leaping. The foot being upon the ground, the limb rotates upon it as an axis, carrying the body forward and slightly elevating it, but the elevation is in the arc of a circle, and when the other foot reaches the ground the body is slightly lowered. Thus in progression the trunk continually rises and falls; it really undulates along a given line.

But other motions than those referred to are developed in the act of walking. The movements of the arms and feet are complementary; the right foot and left arm advance together, and *vice versa*. This begets a diagonal movement which produces oscillation or twisting of the trunk, which is excessive in awkward walkers. To repress this oscillatory swing is indispensable, if great velocity is to be attained. Trained runners flex their arms and hold them steadily at their greatest speed, and every school-boy does the same instinctively, without considering why the act is important. The swiftest-running birds have small wings; those of the ostrich are scarcely more than rudimental.

FIG. 8.



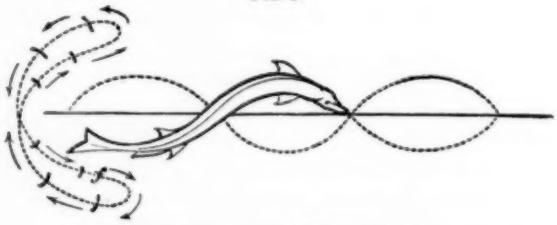
SWIMMING OF THE FISH—(After Borelli.)

The diagonal twist or movement referred to is expressed in a spiral wave of motion which traverses the trunk in the direction of its length. This motion is obvious in fishes in the act of swimming. It is a resultant of motions, which are in all vertebrates essentially the same. In the walking of a cat or panther, this wave of curvature is continuous along the spine. It is really a lateral undulation. We will

follow this curved motion in the swimming of aquatic animals. The illustration of Borelli (Fig. 8), shows only a single curve of the body.

Prof. Owen, commenting on this figure, says the tail of the animal moving from *a* to *i* causes the centre of gravity to move forward, and turns the head of the fish in the direction *c* to *h*. This implies but a single curve of the body, whereas there are two, the one complementary of the other, as is shown to be the case by Dr. Pettigrew. He says: "Observation and experiment have convinced me that when a fish swims it never throws its body into a single curve, as represented in Borelli's figure, but always in a double or figure-of-8 curve, as shown in Fig. 9.

FIG. 9.



SWIMMING OF THE STURGEON.

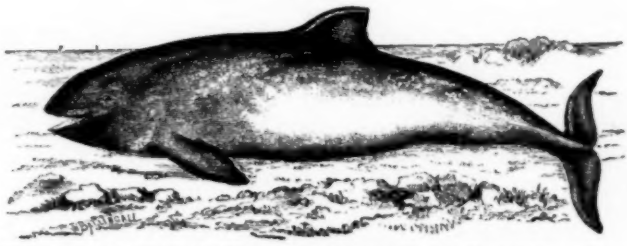
In swimming, the body of the fish describes a waved track along a medial line. The two curves of the body act as fulcra for each other, as occurs in the movement of a snake, by its usual lateral undulations when swimming. In fishes and swimming reptiles of great length, there may occur more than two curves, as four, but never three, each curve having its complementary one. "The fish lashes its tail from side to side, and a figure-of-8 track is formed by the movement," both strokes propelling, but with unequal power during the course of the stroke. There is a feature in this movement which is equally obvious in the movement of the wings of birds in the air, that is, a current is formed, as the tail is carried to one side, against which the return-stroke is given; thus, as the author observes, "the tail may be said to work without slip, and to produce the precise kind of currents which afford it the greatest leverage."

And this is true, whether the swing of the tail in swimming is sideways, as with the salmon, or vertically, as occurs with the whale or the porpoise. The fins act as balancers of the body, but the equipoise is impaired if they are injured; and the removal of the tail, as Owen observes, destroys the power of locomotion.

The specific gravity of aquatic animals is nearly that of the water they inhabit, or is made so in many cases by the gaseous contents of their air-bladders. Nevertheless, momentum is an important element in swimming. It originates in the movement of the fins and tail, and not from throwing the body forward, as occurs in the initial movement of walking. The momentum and velocity attained by some

fishes are astonishingly great. A blow from the head of a sperm-whale may endanger a strong ship, and the sword of a sword-fish has been driven through the oak-planks of a vessel more than twelve inches in thickness.

FIG. 10.



THE PORPOISE.—Here the tail is principally engaged in swimming, the anterior extremities being rudimentary, and resembling the pectoral fins of fishes.

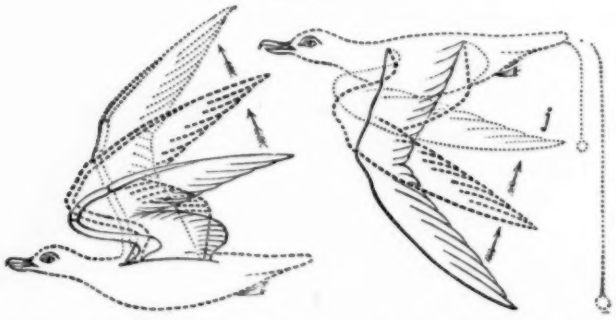
When the flying-fish rises in the air, it is by the momentum it attains in the water by the lashing of its fins and tail. Fairly in the air, its wings give it support, and, in the opinion of Dr. Pettigrew, act as true pinions within certain limits, but are too small to sustain the creature indefinitely.

The transition from swimming to progression in the air is natural and easy. The method by which the flying-fish rises from the water is similar to that of the albatross, that prince of flying-birds, and, indeed, to perhaps all other birds, when in the act of taking flight upon the water. Momentum is obtained by rushing forward with both feet and wings. The albatross frequently goes in this way many rods before it is fairly launched upon the air. Then, with powerful strokes, it rises above the waves. Its expenditure of force is chiefly in rising, when, without further effort, except to screw and unscrew its pinions upon the wind, it floats facing the gale. For more than an hour it will sail with wings apparently motionless, and it seems most at rest when the winds are highest. In this case it is sustained by the momentum it attained, and the wonderful kite-like position and adjustment of its wings. But, it manifestly could not maintain its position in this way, if moving before the wind, or in a perfectly calm atmosphere. The wings must then be called into play to afford lifting as well as propelling power. The momentum must be supplied.

Birds rise from the ground most readily facing the wind, but usually run or leap, and the wings, by vigorous strokes, continue the impulse secured. With the first down-stroke of the wings the body is lifted, and some velocity attained; when the wings rise, the body falls somewhat, but is at the same time advancing. This rise and fall of the body in flying continue, and the body, in progressing, undulates above and below a given line. In the flight of birds with large wings and slow stroke, it is easily observed. The illustration, Fig. 11, shows

the positions of the wings of the gull in the course of a complete oscillation:

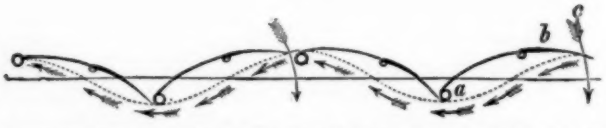
FIG. 11.



SHOWING THE MORE OR LESS PERPENDICULAR DIRECTION OF THE STROKE OF THE WING IN THE FLIGHT OF THE GULL.

When the down-stroke is completed the bird has been raised, but is lowered again when the wings have attained their maximum elevation. Thus it is seen how directly gravity aids in flight. The body is the weight; the wings are long levers attached to it at one end; the air is the fulcrum. Fig. 12 shows the undulatory track of a flying-bird:

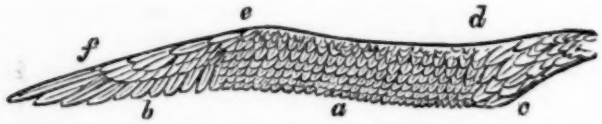
FIG. 12.



BIRD at *a*; down-stroke of the wing, *b*, lifts the bird to *c*—the track of the bird being in direction of the arrows.

The instant the descent of the wing begins, the body moves upward and forward; but it is shown by the author that some forward motion results also from the up-stroke. Certain it is that the upward movement must not counteract the other. There is no provision for

FIG. 13.



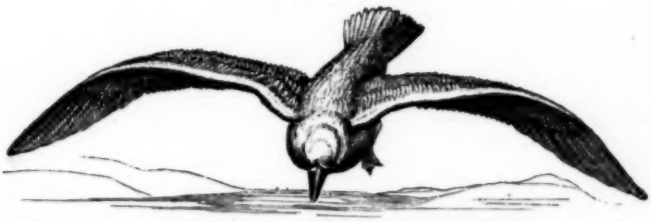
LEFT WING OF THE ALBATROSS.—*d*, *e*, *f*, Anterior or thick margin of pinion; *b*, *a*, *c*, Posterior or thin margin, composed of the primary (*b*), secondary (*a*), and tertiary (*c*) feathers.

waste of energy. The form of the upper surface of the wing is convex, the under surface being concave. The value of this will be apparent, as the Duke of Argyle suggests, if we attempt to move the

concave or convex side of an umbrella against the wind; one side holds the air, the other discharges it. The wing of the albatross shows how completely the feathers are adjusted, on the upper side, to avoid any hold upon the ai .

This arrangement, with the flexibility and screw-like motion of the wings of the gull, shown in Fig. 14, explains the exceedingly small resistance experienced in the upward movement, and also the forward impetus which it communicates.

Fig. 14.



Shows the Twisted Levers or Screws formed by the Wings of the Gull.

It is in the down-stroke, or, as Dr. Pettigrew insists, in the beginning of the down-stroke, that force is chiefly expended. This movement is essentially a muscular act, and by this force alone no bird could sustain long-continued flight. The lark, whose flight is upward, soon descends to the earth. It lifts itself against gravity, simply by expenditure of vital force. But, the moment forward motion is attained, other forces relieve the strain upon the pinions, and their inclined surfaces convert gravity into a propelling power. It is obvious, however, that flight is attended with considerable muscular exertion. Migrating birds alight in unsuitable positions for rest, but the swallow will fly 1,000 miles in a single journey, and the condor attains an altitude of six miles.

The heron will strike the air 60 times in a minute, which, with 60 up-strokes, gives 120 movements, and this is continued through long

Fig. 15.

The Gray Heron in Full Flight.

flights; and the same is true of many ducks and land-birds which strike the air with extreme and apparently exhausting rapidity. So swift are the motions of the wings of the humming-bird that they produce only a blurred spot before the eye.

That wings act as true kites, when in motion, is a familiar obser-

vation, but they are kites which continually change their surfaces and position in respect to the air, which artificial kites do not. An important difference between them is the rigidity of the one and the wonderful flexibility of the other. The kite rises as its oblique surface is pressed against the elastic air; the same is true of the wing. But the wing rotates, so that the proper obliquity of its parts is continually maintained; it rolls on and off the wind; it rotates not only throughout its length, but in each of its parts. The quills, which are convex, rotate, and present closed or oblique surfaces, which hold or discharge the air.

We have space for but one more of the numerous diagrams and figures which Dr. Pettigrew has prepared, illustrating the phenomena of flight. Fig. 16 is of the extended wing of a partridge, seen from beneath and from behind.

FIG. 16.

CURVES IN THE WING OF A PARTRIDGE IN FLIGHT.

The wings, when flexed and extended in flight, assume curved surfaces, which change at each instant and carve the air, as does the tail of the fish the water, into complex wave-lines; and such is the structure of the wing that these results are inevitable when it is put in motion. "The muscles, bones, ligaments, and feathers, are so adjusted with reference to each other that, if the wing is moved at all, it must move in the proper direction." The bird no more thinks of its motions in flying than we do of ours in walking; the actions are mechanical and instinctive. An opinion long prevailed that heated air in the hollow bones of the bird gave it buoyancy and power of flight. This is shown to be a fallacy.

Three principal forces are expressed in flight: muscular and elastic force of the wing, weight of the body, and recoil of the air. By the mechanical structure of the wing, these forces act, react, and combine. Thus birds traverse the aërial ocean; the wild-goose drives his train along invisible tracks; the albatross and petrel are at home in the gale, undisturbed by its clamor; and the condor, with easy motion, treads with his pinions the elastic floors of the upper air.

The more rapid the strokes of the wing the greater the achievement. Not so with one of the most ingenious of human contrivances for progression. The screw, if urged beyond a certain velocity, holds and carries with it the water, and its propelling power is lost. It wants the flexibility of the wing and the fin—the adaptation is not complete.

REPLIES TO THE QUARTERLY REVIEWERS.

By HERBERT SPENCER.

WITH the concluding paragraph of the previous article replying to criticisms I had hoped to end, for a long time, all controversial writing. But, while it was in the printer's hands, two criticisms, more elaborate than those dealt with above, made their appearance; and, now that the postponed publication of this latter half of the article affords the opportunity, I cannot, without risking misinterpretations, leave these criticisms unnoticed.

Especially do I feel called upon by courtesy to make some response to one who, in the *Quarterly Review*, for October, has dealt with me in a spirit which, though largely antagonistic, is not wholly unsympathetic, and who manifestly aims to estimate justly the views he opposes. In the space at my disposal, I cannot of course follow him through all the objections he has urged. I must content myself with brief comments on the two propositions he undertakes to establish. His enunciation of these runs as follows:

"We would especially direct attention to two points, to both of which we are confident objections may be made; and, although Mr. Spencer has himself doubtless considered such objections (and they may well have struck many of his readers also), we nevertheless do not observe that he has anywhere noticed or provided for them.

"The two points we select are:

"1. *That his system involves the denial of all truth.*

"2. *That it is radically and necessarily opposed to all sound principles of morals.*"

On this passage, ending in these two startling assertions, let me first remark that I am wholly without this consciousness the reviewer ascribes to me. Remembering that I have expended some little labor in developing what I conceive to be a system of truths, I am somewhat surprised by the supposition that "the denial of all truth" is an implication which I am "doubtless" aware may be alleged against this system. Remembering, too, that by its programme this system is shown to close with two volumes on "The Principles of Morality," the statement that it is "necessarily opposed to all sound principles of morals" naturally astonishes me, and still more the statement that I am doubtless conscious it may be so regarded. Saying thus much by way of repudiating that latent skepticism attributed to me by the reviewer, I proceed to consider what he says in proof of these propositions.

On those seeming incongruities of Transfigured Realism commented on by him, I need say no more than I have already said in reply to Mr. Sidgwick, by whom also they have been alleged. I

will limit myself to the corollary he draws from the doctrine of the Relativity of Knowledge, as held by me. Rightly pointing out that I hold this in common with "Messrs. Mill, Lewes, Bain, and Huxley," but not adding, as he should have done, that I hold it in common with Hamilton, Mansel, and the long list of predecessors through whom Hamilton traced it, the reviewer proceeds to infer from this doctrine of relativity that no absolute truth of any kind can be asserted—not even the absolute truth of the doctrine of relativity itself. And then he leaves it to be supposed by his reader that this inference tells especially against the system he is criticising. If, however, the reviewer's inference is valid, this "denial of all truth" must be charged against the doctrines of thinkers called orthodox, as well as against the doctrines of those many philosophers, from Aristotle down to Kant, who have said the same thing. But now I go further, and reply that, against that form of the doctrine of relativity held by me, this allegation cannot be made with the same effect as it can against preceding forms of the doctrine. For I diverge from other relativists in asserting that the existence of a non-relative is not only a positive deliverance of consciousness, but a deliverance transcending in certainty all others whatever, and is one without which the doctrine of relativity cannot be framed in thought. I have urged that, "unless a real Non-relative or Absolute be postulated, the Relative itself becomes absolute, and so brings the argument to a contradiction;"[1] and elsewhere I have described this consciousness of a Non-relative manifested to us through the Relative as "deeper than demonstration—deeper even than definite cognition—deep as the very nature of mind;"[2] which seems to me to be saying as emphatically as possible that, while all other truths may be held as relative, this truth must be held as absolute. Yet, strangely enough, though contending thus against the pure relativists, and holding with the reviewer, that "every asserter of such a (purely-relative) philosophy must be in the position of a man who saws across the branch of a tree on which he actually sits, at a point between himself and the trunk,"[3] I am singled out by him as though this were my own predicament. So far, then, from admitting that the view I hold "involves the denial of all truth," I assert that, having at the outset posited the coexistence of subject and object as a deliverance of consciousness which precedes all reasoning[4]—having subsequently shown, analytically, that this postulate is in every way verified,[5] and that in its absence the proof of relativity is impossible—my view is distinguished by an exactly-opposite trait.

The justification of his second proposition the reviewer commences by saying that "in the first place the process of Evolution, as understood by Mr. Spencer, compels him to be at one with Mr. Darwin in

[1] "First Principles," § 26. [2] Ibid., § 62.
[3] Compare "Principles of Psychology," §§ 88, 95, 391, 401, 406.
[4] "First Principles," §§ 39, 45. [5] "Principles of Psychology," part vii.

his denial of the existence of any fundamental and essential distinction between Duty and Pleasure." Following this by a statement respecting the genesis of moral sentiments as understood by me (which is extremely unlike the one I have given in the "Principles of Psychology" (§ 215, §§ 503–512, and §§ 524–532), the reviewer goes on to say that "we yield with much reluctance to the necessity of affirming that Mr. Spencer gives no evidence of ever having acquired a knowledge of the meaning of the term 'morality,' according to the true sense of the word."

Just noting that, as shown by the context, the assertion thus made is made against all those who hold the Doctrine of Evolution in its unqualified form, I reply that, in so far as it concerns me, it is one the reviewer would scarcely have made had he more carefully examined the evidence—not limiting himself to those works of mine named at the head of his article. And I cannot but think that, had the spirit of fairness, which he evidently strives to maintain, been fully awake when these passages were written, he would have seen that, before making so serious an allegation, wider inquiry was needful. If he had simply said that, given the doctrine of mental evolution as held by me, he failed to see how moral principles were to be established, I should not have objected; provided he had also said that I believe they can be established, and had pointed out what I hold to be their bases. As it is, however, he has so presented his own inference from my premises as to make it seem an inference which I also must draw from my premises. Quite a different and much more secure foundation for moral principles is alleged by me than that afforded by moral sentiments and conceptions, which he refers to as though they formed the sole basis of the ethical conclusions I hold. While the reviewer contends that "Mr. Spencer's moral system is even yet more profoundly defective, as it denies any objective distinction between right and wrong in any being, whether men are or are not responsible for their actions," I contend, contrariwise, that it is distinguished from other moral systems by asserting the objectivity of the distinction, and by endeavoring to show that the subjective distinction is derived from the objective distinction. In my first work, "Social Statics," published twenty-three years ago, the essential thesis is that, apart from their warrant as alleged Divine injunctions, and apart from their authority as moral intuitions, the principles of justice are primarily deducible from the laws of life, as carried on under social conditions. I argued throughout that these principles so derived have a supreme authority, to which considerations of immediate expediency must yield, and I was for this reason classed by Mr. Mill as an anti-utilitarian. More recently, in a letter drawn from me by this misapprehension of Mr. Mill, and afterward published by Prof. Bain in his "Mental and Moral Science," I have restated this position. Already, in an explanatory article entitled "Morals and Moral Sentiments,"

published in this *Review* for April, 1871, I have quoted passages from that letter; and here, considering the gravity of the assertions made by the *Quarterly* reviewer, I hope to be excused for requoting them:

"Morality, properly so called—the science of right conduct—has for its object to determine *how* and *why* certain modes of conduct are detrimental, and certain other modes beneficial. . These good and bad results cannot be accidental, but must be necessary consequences of the constitution of things; and I conceive it to be the business of Moral Science to deduce, from the laws of life and the conditions of existence, what kinds of action necessarily tend to produce happiness, and what kinds to produce unhappiness. Having done this, its deductions are to be recognized as laws of conduct, and are to be conformed to irrespective of a direct estimation of happiness or misery."

. . . . . .

"If it is true that pure rectitude prescribes a system of things far too good for men as they are, it is not less true that mere expediency does not of itself tend to establish a system of things any better than that which exists. While absolute morality owes to expediency the checks which prevent it from rushing into Utopian absurdities, expediency is indebted to absolute morality for all stimulus to improvement. Granted that we are chiefly interested in ascertaining what is *relatively right*, it still follows that we must first consider what is *absolutely right;* since the one conception presupposes the other."

And the comment I then made on these passages I may make now, that "I do not see how there could well be a more emphatic assertion that there exists a primary basis of morals independent of, and in a sense antecedent to, that which is furnished by experiences of utility, and consequently independent of, and in a sense antecedent to, those moral sentiments which I conceive to be generated by such experiences." I will only add that, had my beliefs been directly opposite to those I have enunciated, the reviewer might, I think, have found good reasons for his assertion. If, instead of demurring to the doctrine that "greatest happiness should be the *immediate* aim of man,"[1] I had indorsed that doctrine—if, instead of explaining and justifying "a belief in the special sacredness of these highest principles, and a sense of the supreme authority of the altruistic sentiments answering to them,"[2] I had denied the sacredness and the supreme authority—if, instead of saying of the wise man that "the highest truth he sees he will fearlessly utter, knowing that, let what may come of it, he is thus playing his right part in the world,"[3] I had said that the wise man will *not* do this—the reviewer might with some truth have described me as not understanding "the term 'morality' according to the true sense of the word." And he might then have inferred that the Doctrine of Evolution, as I hold it, implies denial of the "distinction between Duty and Pleasure." But, as it is, I think the evidence will not generally be held to warrant his assertion.

I quite agree with the reviewer that the prevalence of a philosophy

[1] "Social Statics," chapter iii.
[2] "Principles of Psychology," § 531.
[3] "First Principles," § 34.

"is no mere question of speculative interest, but is one of the highest practical importance." I join him, too, in the belief that "calamitous social and political changes" may be the outcome of a mistaken philosophy. Moreover, writing as he does under the conviction that there can be no standard of right and wrong save one derived from a Revelation interpreted by an Infallible Authority, I can conceive the alarm with which he regards so radically-opposed a system. Though I could have wished that the sense of justice he generally displays had prevented him from ignoring the evidence I have above given, I can understand how, from his point of view, the Doctrine of Evolution, as I understand it, "seems absolutely fatal to every germ of morality," and "entirely negatives every form of religion." But I am unable to understand that modified doctrine of Evolution which the reviewer proposes as an alternative. For, little as the reader would anticipate it after these expressions of profound dissent, the reviewer displays such an amount of agreement as to suggest that the system he is criticising might be converted, "rapidly and without violence, into an 'allotropic state,' in which its conspicuous characters would be startlingly diverse from those that it exhibits at present." May I, using a different figure, suggest a different transformation, having a subjective instead of an objective character? As, in a stereoscope, the two views, representing diverse aspects, often yield at first a jumble of conflicting impressions, but after a time suddenly combine into a single whole which stands out quite clearly, so, may it not be that the seemingly-inconsistent Idealism and Realism dwelt on by the reviewer, as well as the other seemingly-fundamental incongruities he is struck by, will, under more persistent contemplation, unite as complementary sides of the same thing?

My excuse, for devoting so much space to a criticism of so entirely different a kind as that contained in the *British Quarterly Review* for October, must be that, under the circumstances, I cannot let it pass unnoticed without seeming to admit its validity.

Saying that my books should be dealt with by specialists, and tacitly announcing himself as an expert in Physics, the reviewer takes me to task both for errors in the statement of physical principles and for erroneous reasoning in physics. That he discovers no mistakes I do not say. It would be marvelous if, in such a multitude of propositions, averaging a dozen per page, I had made all criticism-proof. Several are inadvertencies which I should have been obliged to the reviewer for pointing out as such, but which he prefers to instance as proving my ignorance. In other cases, taking advantage of an imperfection of statement, he proceeds to instruct me about matters which either the context, or passages in the same volume, show to be quite familiar to me. Here is a sample of his criticisms belonging to this class:

"Nor should we counsel a man to venture upon physical speculations who converts the proposition '*heat is insensible motion*' into '*insensible motion is heat*,' and hence concludes that when a force is applied to a mass so large that no motion is seen to result from it, or when, as in the case of sound, motion gets so dispersed that it becomes insensible, it turns to heat."

Respecting the first of the two statements contained in this sentence, I will observe that the reader, if not misled by the quotation-marks into the supposition that I have made, in so many words, the assertion that "insensible motion is heat," will at any rate infer that this assertion is distinctly involved in the passage named. And he will infer that the reviewer would never have charged me with such an absurd belief, if there was before him evidence proving that I have no such belief. What will the reader say, then, when he learns, not simply that there is no such statement, and not simply that on the page referred to, which I have ascertained to be the one intended, there is no such implication visible, even to an expert (and I have put the question to one), but when he further learns that, in other passages, the fact that heat is the one only of modes of insensible motion is distinctly stated (*see* "First Principles," §§ 66, 68, 171), and when he learns that elsewhere I have specified the several forms of insensible motion? If the reviewer, who looks so diligently for flaws as to search an essay in a volume he is not reviewing to find one term of an incongruity, had sought with equal diligence to learn what I thought about insensible motion, he would have found in the "Classification of the Sciences," Table II., that insensible motion is described by me as having the forms of heat, light, electricity, magnetism. Even had there been, in the place he names, an unquestionable implication of the belief which he ascribes to me, fairness might have led him to regard it as an oversight, when he found it at variance with statements I have elsewhere made. What, then, is to be thought of him when, in the place named, no such belief is manifest, either to an ordinary reader or a specially-instructed reader?

No less significant is the state of mind betrayed in the second clause of the reviewer's sentence. By representing me as saying that, when the motion constituting sound "gets so dispersed that it becomes insensible, it turns to heat," does he intend to represent me as thinking that, when sound-undulations become too weak to be audible, they become heat-undulations? If so, I reply that the passage he refers to has no such meaning. Does he then allege that some part of the force diffused in sound-waves is expended in generating electricity, by the friction of heterogeneous substances (which, however, eventually lapses from this special form of molecular motion in that general form constituting heat), and that I ought to have thus qualified my statement? If so, he would have had me commit a piece of scientific pedantry hindering the argument. If he does not mean either of these things, what does he mean? Does he contest the truth of the

hypothesis which enabled Laplace to correct Newton's estimate of the velocity of sound—the hypothesis that heat is evolved by the compression each sound-wave produces in the air? Does he deny that the heat so generated is at the expense of so much wave-motion lost? Does he question the inference that some of the motion embodied in each wave is from instant to instant dissipated, partly in this way and partly in the heat evolved by fluid friction? Can he show any reason for doubting that, when the sound-waves have become too feeble to affect our senses, their motion still continues to undergo this transformation and diminution until it is all lost? If not, why does he implicitly deny that the molar motion constituting sound eventually disappears in producing the molecular motion constituting heat?[1]

I will dwell no longer on the exclusively-personal questions raised by the reviewer's statements, but, leaving the reader to judge of the rest of my "stupendous mistakes" by the one I have dealt with, I will turn to a question worthy to occupy some space, as having an impersonal interest—the question, namely, respecting the nature of the warrant we have for asserting ultimate physical truths. The contempt which, as a physicist, the reviewer expresses for the metaphysical exploration of physical ideas, I will pass over with the remark that every physical question, probed to the bottom, ends in a metaphysical one, and that I should have thought the controversy now going on among chemists, respecting the legitimacy of the atomic hypothesis, might have shown him as much. On his erroneous statement that I use the phrase "Persistence of Force" as an equivalent for the now-generally-accepted phrase "Conservation of Energy," I will observe only that, had he not been in so great a hurry to find inconsistencies, he would have seen why, for the purposes of my argument, I intentionally use the word Force: Force being the generic word, including both that species known as Energy, and that species by which Matter occupies space and maintains its integrity—a species which, whatever may be its relation to Energy, and however clearly recognized as a

[1] Only after the foregoing paragraphs were written, did the remark of a distinguished friend show me how certain words were misconstrued by the reviewer in a way that had never occurred to me as possible. In the passage referred to, I have said that sound-waves "finally die away in generating thermal undulations that radiate into space;" meaning, of course, that the force embodied in the sound-waves is finally *exhausted* in generating thermal undulations. In common speech, the dying away of a prolonged sound, as that of a church-bell, includes its gradual diminution as well as its final cessation. But, rather than suppose I gave to the words this ordinary meaning, the reviewer supposes me to believe, not simply that the *longitudinal* waves of air can pass, *without discontinuity*, into the *transverse* waves of ether, but he also debits me with the belief that the one order of waves, having lengths measurable in feet, and rates expressed in hundreds per second, can *by mere enfeeblement* pass into the other order of waves, having lengths of some fifty thousand to the inch, and rates expressed in many billions per second! Why he preferred so to interpret my words, and that, too, in the face of contrary implications elsewhere (instance § 100), will, however, be manifest to every one who reads his criticisms.

necessary *datum* by the theory of Energy, is not otherwise considered in that theory. I will confine myself to the proposition, disputed at great length by the reviewer, that our cognition of the Persistence of Force is *a priori*. He relies much on the authority of Prof. Tait, whom he twice quotes to the effect that—

> "Natural philosophy is an experimental, and not an intuitive science. No *a priori* reasoning can conduct us demonstratively to a single physical truth."

Were I to take an hypercritical attitude, I might dwell on the fact that Prof. Tait leaves the extent of his proposition somewhat doubtful, by speaking of "Natural philosophy" as *one* science. Were I to follow further the reviewer's example, I might point out that "Natural philosophy," in that Newtonian acceptation adopted by Prof. Tait, includes Astronomy; and, going on to ask what astronomical "experiments" those are which conduct us to astronomical truths, I might then "counsel" the reviewer not to depend on the authority of one who (to use the reviewer's polite language) "blunders" by confounding experiment and observation. I will not, however, thus infer from Prof. Tait's imperfection of statement that he is unaware of the difference between the two; and shall rate his authority as of no less value than I should had he been more accurate in his expression. Respecting that authority I shall simply remark that, if the question had to be settled by the authority of any physicist, the authority of one who is diametrically opposed to Prof. Tait on this point, and who has been specially honored, both by the Royal Society and by the French Institute, might well counterweigh his, if not outweigh it. I am not aware, however, that the question is one in Physics. It seems to me a question respecting the nature of proof. And, without doubting Prof. Tait's competence in Logic and Psychology, I should decline to abide by his judgment on such a question, even were there no opposite judgment given by a physicist, certainly of not less eminence.

Authority aside, however, let us discuss the matter on its merits. In the "Treatise on Natural Philosophy," by Profs. Thomson and Tait, § 243, I read that, "as we shall show in our chapter on 'Experience,' physical axioms are axiomatic to those only who have sufficient knowledge of the action of physical causes to enable them to see at once their necessary truth." In this I agree entirely. It is in Physics, as it is in Mathematics, that, before necessary truths can be grasped, there must be gained, by individual experience, such familiarity with the elements of the thoughts to be framed that propositions about those elements may be mentally represented with distinctness. Tell a child that things which are equal to the same thing are equal to one another, and the child, lacking a sufficiently abstract notion of equality, and lacking, too, the needful practice in comparing relations, will fail to grasp the axiom. Similarly, a rustic, never having thought much about forces and their results, cannot form a definite conception

answering to the axiom that action and reaction are equal and opposite. In the last case, as in the first, ideas of the terms and their relations require to be made, by practice in thinking, so vivid that the involved truths may be mentally seen. But when the individual experiences have been multiplied enough to produce distinctness in the representations of the elements dealt with, then, in the one case, as in the other, those mental forms, generated by ancestral experiences, cannot be occupied by the elements of one of these ultimate truths without perception of its necessity. If Prof. Tait does not admit this, what does he mean by speaking of "physical *axioms*," and by saying that the cultured are enabled "to see *at once* their *necessary* truth?"

Again, if there are no physical truths which must be classed as *a priori*, I ask why Prof. Tait joins Sir W. Thomson in accepting, as bases for Physics, Newton's Laws of Motion? Though Newton gives illustrations of prolonged motion in bodies that are little resisted, he gives no *proof* that a body in motion will continue moving, if uninterfered with, in the same direction at the same velocity; nor, on turning to the enunciation of this law, quoted in the above-named work, do I find that Prof. Tait does more than exemplify it by facts which can themselves be asserted only by taking the law for granted. Does Prof. Tait deny that the first law of motion is a physical truth? If so, what does he call it? Does he admit it to be a physical truth, and, denying that it is *a priori*, assert that it is established *a posteriori*—that is, by conscious induction from observation and experiment? If so, what is the inductive reasoning which can establish it? Let us glance at the several conceivable arguments which we must suppose him to rely on.

A body set in motion soon ceases to move if it encounters much friction, or much resistance from other bodies struck. If less of its energy is expended in moving, or otherwise affecting, other bodies, or in overcoming friction, its motion continues longer. And it continues longest when, as over smooth ice, it meets with the smallest amount of obstruction from other matter. May we then, proceeding by the method of concomitant variations, infer that were it wholly unobstructed its motion would continue undiminished? If so, we assume that the diminution of its motion observed in experience is proportionate to the amount of energy abstracted from it in producing other motion, either molar or molecular. We assume that no variation has taken place in its rate, save that caused by deductions in giving motion to other matter; for, if its motion be supposed to have otherwise varied, the conclusion, that the differences in the distances traveled result from differences in the obstructions met with, is vitiated. Thus the truth to be established is already taken for granted in the premises. Nor is the question begged in this way only. In every case where it is remarked that a body stops the sooner, the more it is obstructed by other bodies or media, the law of inertia is assumed to hold in the obstructing bodies or media. The very conception of greater or less

retardation so caused, implies the belief that there can be no retardations without proportionate retarding causes; which is itself the assumption otherwise expressed in the first law of motion.

Again, let us suppose that, instead of inexact observations made on the movements that occur in daily experience, we make exact experiments on movements specially arranged to yield measured results; what is the postulate underlying every experiment? Uniform velocity is defined as motion through equal spaces in equal times. How do we measure equal times? By an instrument which can be inferred to mark equal times only if the oscillations of the pendulum are isochronous; which they can be proved to be only if the first and second laws of motion are granted. That is to say, the proposed experimental proof of the first law assumes not only the truth of the first law, but of that which Prof. Tait agrees with Newton in regarding as a second law. Is it said that the ultimate time-measure referred to is the motion of the Earth round its axis, through equal angles in equal times? Then, the obvious rejoinder is, that the assertion of this similarly involves an assertion of the truth to be proved; since the undiminished rotatory movement of the Earth is itself a corollary upon the first law of motion. Is it alleged that this axial movement of the Earth through equal angles in equal times is ascertainable by reference to the stars? I answer, that a developed system of Astronomy, leading through complex reasonings to the conclusion that the Earth rotates, is, in that case, supposed to be needful before there can be established a law of motion which this system of Astronomy itself postulates. For, even should it be said that the Newtonian theory of the Solar System is not necessarily presupposed, but only the Copernican, still the proof of this assumes that a body at rest (a star being taken as such) will continue at rest; which is a part of the first law of motion, regarded by Newton as not more self-evident than the remaining part.

Not a little remarkable, indeed, is the oversight made by Prof. Tait, in asserting that "no *a priori* reasoning can conduct us demonstratively to a single physical truth," when he has before him the fact that the system of physical truths constituting Newton's "Principia," which he has joined Sir William Thomson in editing, is established by *a priori* reasoning. That there can be no change without a cause, or, in the words of Mayer, that "a force cannot become nothing, and just as little can a force be produced from nothing," is that ultimate dictum of consciousness on which all physical science rests. It is involved alike in the assertion that a body at rest will continue at rest, in the assertion that a body in motion must continue to move at the same velocity in the same line if no force acts upon it, and in the assertion that any divergent motion given to it must be proportionate to the deflecting force; and it is also involved in the axiom that action and reaction are equal and opposite.

The reviewer's doctrine, in support of which he cites against me

the authority of Prof. Tait, illustrates in Physics that same error of the inductive philosophy which, in Metaphysics, I have pointed out elsewhere ("Principles of Psychology," Part VII.). It is a doctrine implying that we can go on forever asking the proof of the proof, without finally coming to any deepest cognition which is unproved and unprovable. That this is an untenable doctrine I need not say more to show. Nor, indeed, would saying more to show it be likely to have any effect, in so far at least as the reviewer is concerned; seeing that he thinks I am "ignorant of the very nature of the principles" of which I am speaking, and seeing that my notions of scientific reasoning "remind" him "of the Ptolemists," who argued that the heavenly bodies must move in circles because the circle is the most perfect figure.[1]

Not to try the reader's patience further, I will end by pointing out that, even were the reviewer's criticisms all valid, they would leave unshaken the system he contends against. Though one of his sentences (page 480) raises the expectation that he is about to assault, and greatly to damage, the fabric of propositions contained in the second part of "First Principles," yet all those propositions which constitute the fabric he leaves not only uninjured but even untouched, contenting himself with trying to show (with what success we have seen) that the fundamental one is an *a posteriori* truth, and not an *a priori* truth. Against the general Doctrine of Evolution, considered as an induction from all concrete phenomena, he utters not a word; nor does he utter a word to disprove any one of those laws of the redistribution of matter and motion by which the process of Evolution is deductively interpreted. Respecting the law of the Instability of the Homogeneous, he says no more than to quarrel with one of the illustrations. He makes no criticism on the law of the Multiplication of Effects. The law of Segregation he does not even mention. Nor does he mention the law of Equilibration. Further, he urges nothing against the statement that these general laws are severally deducible from the ultimate law of the Persistence of Force. Lastly, he does not deny the Persistence of Force, but only differs respecting the na-

[1] Other examples of these amenities of controversy, in which I decline to imitate my reviewer, have already been given. What occasions he supplies me for imitation, were I minded to take advantage of them, an instance will show. Pointing out an implication of certain reasonings of mine, he suggests that it is too absurd even for me to avow explicitly, saying: "We scarcely think that even Mr. Spencer will venture to claim as a datum of consciousness the Second Law of Motion, with its attendant complexities of component velocities," etc. Now, any one who turns to Newton's "Principia" will find that to the enunciation of the Second Law of Motion nothing whatever is appended but an amplified restatement—there is not even an illustration, much less a proof. And from this law, this axiom, this immediate intuition or "datum of consciousness," Newton proceeds forthwith to draw those corollaries respecting the composition of forces which underlie all dynamics. What, then, must be thought of Newton, who explicitly assumes that which the reviewer thinks it absurd to assume implicitly?

ture of our warrant for asserting it. Beyond pointing out here a cracked brick, and there a coin set askew, he merely makes a futile attempt to show that the foundation is not natural rock, but concrete.

From his objections I may, indeed, derive much satisfaction. That a competent critic, obviously anxious to do all the mischief he can, and not over-scrupulous about the means he uses, has done so little, may be taken as evidence that the fabric of conclusions attacked will not be readily overthrown.

PHYSIOLOGY OF THE PASSIONS.

By FERNAND PAPILLON.

TRANSLATED FROM THE FRENCH, BY J. FITZGERALD, A. M.

IF there is to-day a fact demonstrated by reason reflexly contemplating itself no less than by attentive observation of the entire development of human knowledge, it is the close interdependence of all natural forces and operations—a solidarity so firmly knit that it is impossible to study any one point of detail without reference to the sum total of the phenomena. The sciences, long kept apart from one another, now all tend to come together, to fuse into one another, for the explication of facts. It is the exigencies of the science of man that, above all, have determined this irresistible attraction, this systematic confluence of branches of knowledge the most diverse toward one centre, where they attain their full value and their full significance. Man brings together within himself, as Buffon says, all the powers of Nature: he is the centre to which all things are referred—a world in miniature; no amount of analysis can come amiss, if we are to resolve the endless complexity of this so multiple being; and we need all the light we can get, in order to illumine the darkness that surrounds this mysterious creature. If, as Leibnitz thinks, one single monad—an imperceptible atom—is a mirror of the total beauty of the universe, how much more truly may this be said of that singular and diversified assemblage of monads, man! Surely it would ill become us to disparage the psychologist, whose study has been to get at a knowledge of man solely by observation of the phenomena of consciousness; or the physiologist, who has attempted to find an explication solely in organic phenomena. Both of these have, with much toil, broken the ground and prepared a field where investigation may henceforth bear fruit; but, precisely because the soil is now ready, it is to be hoped that the controversies and antagonisms of the past will give way to a good understanding, more conducive to a true knowledge of man's nature; and that inquiry, instead of diverging

and so losing itself, shall be regulated and coördinated to the attainment of one end.

These reflections are addressed neither to those who imagine that psychology has done all its work already, nor to those who think that work never can be done; we submit them to those who, following attentively the double movement of physiology and of psychology, find that, at least, the progress made by each of these sciences is correlative with that made by the other, and inseparable from it. Philosophers, whose position and whose previous inquiries seemed very unlikely to invite them to the study of physical man, now devote themselves to this study with enlightened ardor. Experimenters, whose reputation and whose habits might appear very unapt to incline them toward the study of moral man, now pursue that study with conscientious diligence. The result is, a profounder and more precise science of the relations between the physical and the moral—a science that is full of revelations and surprises.

I.

The ancients had a theory with regard to the passions which, at bottom, differs not much from that countenanced in these later times, by experimental physiology and pathology. They erred with regard to the *rôle* of the humors and the physiological mechanism in the production of passional phenomena; but they had closely observed, and, with rare precision, defined the influence exerted by these on the viscera of the abdominal region. Their poetry and their medical writings are full of expressions which show how ancient is the knowledge of this relation between the soul's sentiments and the movements of heart, lungs, stomach, and liver.[1] The ancients even went so far as to localize the passions in the viscera; and their theory on this subject is expressed in the aphorism, "*Splene* rident, *felle* irascunt, *jecore* amant, *pulmone* jactantur," where the *spleen*, the *gall-bladder*, the *liver*, and the *lungs*, are represented as the seat respectively of mirth, anger, love, and vainglory. The physiology of the passions, so far as it could be and was studied by the authors of ancient times, was, from the stand-point of description, a science of such exactitude that there is now little to be added to it. Still, they mistook the real seats of those states of the soul; and Descartes, in his famous work on the passions, was the first to hold that their seat is in the brain. He localized all passional states in that organ. "The soul," he says, "can suffer directly only through the brain;" and, in another place, "The

[1] "Reason sits arbitress within the breast;
For there it is our conscious being dwells;
There fear and dread anxiety creep chill,
And soothing joys play flattering round the heart,
Which shows the soul is there that joys and fears."
LUCRETIUS, C. F. Johnson's translation.

soul does not receive impressions from all parts of the body, but only from the brain." This truth, which now seems so elementary, was nevertheless demonstrated only by the physiology of recent times. The greatest physiological theorist of the passions, Bichat, did not accept it, as we shall see from an exposition of his doctrine.

The first physiological character recognized in the passions, by Bichat, is intermittency. Whereas our thoughts may be continued—prolonged over a considerable period of time—and whereas a habit of making the same reflections and judgments strengthens and perfects them, the passions, on the other hand, have no persistence. With the exception of that pleasure and pain which we might denominate absolute, and which depend on direct nerve-excitation, it may be asserted that a habit of the same sentiments will soon blunt and weaken them. A prolonged sensation, be it pleasant or painful, at last gives neither pleasure nor pain. The perfumer, who is ever surrounded by an odorous atmosphere, does not enjoy the sweet scents. All that delights the eye or charms the ear becomes indifferent when the impression has lasted for some time. The same holds good for disagreeable sensations. "Happiness, therefore," says Bichat, "consists only in incontinuousness. Pleasure is but a comparative sentiment, that ceases to exist where you have uniformity between present and past sensations. Were the forms of all women cast in one mould, that mould were the grave of love."

This profound difference between thought and passion Bichat explains by the theory that the former is dependent on that side of our being which we call *animal life*, while the latter proceeds from the *organic life*. Every thing that has to do with intellectual operations, properly so called, has its seat in the brain, which is the centre of animal life. Every thing that has to do with the passional states has its seat in the viscera. The effect of passion of every kind is to produce some change, some alteration in the organic life, that is to say, in the organs of circulation, of respiration, and of nutrition. This fundamental difference between intelligence and passion, as regards the organs which seem to be their respective seats, has long been remarked by popular sagacity and incorporated into language. Such expressions as "a good head," "a fine-shaped head," have always been employed to express perfection of understanding; and "a good heart," "a tender heart," to express the perfection of sentiment. It has also been a current phrase to say that the blood "boils" with anger, or that indignation "moves" the bile, or that the heart "leaps" with joy. Our gestures accord with our words: thus, when we would in dumb show indicate some state having to do with memory, imagination, perception, or judgment, we bring the hand up to the head. But, when we would express love, joy, hate, disgust, we bring the hand up to the region of the heart or of the stomach.

A close observation of facts proves the correctness of the instincts

that have given rise to these phrases and gestures. It is evident that anger accelerates the circulatory movement, and that joy has the same effect, while grief and fear produce the opposite results. Extreme emotions are sometimes followed by fatal syncope. Profound grief causes a difficulty of respiration. Sudden fright checks the secretion of bile. Independently of these palpable phenomena, the passions modify profoundly the nutritive processes, and give rise to disordered conditions, of a more or less grave nature. Here, again, language accords with physiology. *To pine away with envy*, or *with remorse, to waste away with grief*, are expressions that attest the influence of the passions on the organic life. Again, Bichat ingeniously notes the relation subsisting between the passions and the temperament. The individual whose lungs are highly developed, and whose circulatory system is specially vigorous, will naturally be of very impetuous disposition, choleric, passionate, and courageous. Where the biliary system predominates, enviousness and hate seem to be more habitual. The lymphatic temperament gives to the passions a quiet and indolent character. Thus every thing, according to Bichat, goes to show that the organic life is the terminus to which the passions tend, and the centre from which they start, and that the animal life only suffers from the rebound consecutively. If the focus of the animal life is the brain, then what is the focus of the organic life? What is the apparatus specially concerned in producing emotions and passional manifestations? Bichat holds that there is no one organ on which this office devolves exclusively, and he localizes the passions in what he calls the epigastric centre; that is to say, in the heart, the lungs, the liver, the gall-bladder, and the ganglionic nerve-system, distributed throughout these organs. Each of these is, according to him, the seat of a distinct passion, and the movements that are determined by this passion are perfectly involuntary.

Such is Bichat's doctrine of the passions; it is the ancient doctrine, only developed and elucidated, reasoned out with greater precision, and fortified with fresh proofs. It is correct in its analysis of the visceral disturbances produced by the passions, but erroneous in that it regards the viscera as their main-spring and origin. To Gall belongs the honor of having proved that the passions primarily affect the brain, and not the viscera. It was the experiments made by that great man which showed that the brain is the organ of sentiments no less than of ideas. His argument against Bichat's theory may be reduced to these fundamental observations: The heart and the diaphragm are only muscles, the stomach and the liver only secretory apparatus, the kidneys only an excretory apparatus, and the spleen only a sanguineous gland. Several of these organs may suffer lesion or be removed and still the passions remain; hence we cannot localize the passions in them. Gall, in the next place, examines all the parts of the nervous system outside of the brain, viz., the plexuses, the ganglia, the nerves, and the sensory

apparatus, and shows that here too it is impossible to find the source of our propensities, instincts, affections, or passions. Finally, he examines the brain itself, and in it discovers the exclusive seat of all these activities. That the passions depend essentially on the brain is proved from the fact that any impairment of that viscus determines a perturbation of the passional no less than of the intellectual phenomena. When we see physicians of half a century ago, who were profoundly versed in the study of insanity—a Pinel or an Esquirol, for instance—hesitate about locating in the brain the immediate cause of dementia and the various forms of mania, we can appreciate the importance of the service done by Gall to the science of man, when he rigorously demonstrated the ill-understood functions of the brain, and proved the correctness of Descartes's doctrine of the passions.

The experiments of modern physiologists, those of Claude Bernard in particular, show that all sensations act primarily on the nerve-centres, through the nerves reaching from the periphery of the body to those centres. The excitation thus determined in the brain, or in the spinal cord, is then transferred to the nerve-filaments which extend to the viscera and members, and hence the latter are affected only secondarily. Of all the organs, the heart is the one which earliest and most profoundly experiences the influence of the sensitive excitations produced in the nerve-centres. So soon as any modification whatsoever is produced in the central nerve-substance, the nerves transmit this vibration to the heart, and at once the movements of the latter suffer a perturbation which is expressed in various ways. At one time the nervous action is sufficiently energetic to at once stop the working of the heart; and, as the blood is no longer discharged into the vessels, syncope (fainting) is the result, the skin assuming the pallor and lividness of death. Again, the reverse effect takes place, the beating of the heart being accelerated, instead of being stopped; in this case the blood is forced through the distended vessels to the brain, and there is over-excitation of that organ's activity. The heart is no more the seat of the sentiments than the hand is the seat of the will, but it is a *reactive* which is modified by the sentiments, with the utmost nicety and with infallible certainty. Not only does the heart betray, by the very disturbance of its normal rhythm, the nature of the initial brain-excitation, but it also produces throughout the whole organism disordered actions, the sum of which constitutes, as it were, the physical image, the palpable externals of passion. But it produces this disordered action only by reacting on the brain, which is the organ of all the demonstrations and of all the movements of the nerves, and consequently of the muscles. Thus it is that the heart and the brain, the blood-system and the nerve-system, conspire in the production of passional phenomena, by a series of alternate actions and reactions.

Such, are at least, the chief points of Claude Bernard's doctrine, as set forth at a famous Sorbonne *conférence*, in 1864. At that period the

nature of the nerve-connections of the heart with the brain were as yet unknown, and a Russian physiologist, E. Cyon, has, for some years past, labored successfully to fill up this gap. The heart is provided with a number of little self-acting nerve-ganglia, without relations to the brain, from which spring, under the influence of the blood, a certain number of motor impulsions. These ganglia govern the usual normal action of the cardiac apparatus; but the rhythm and the force of the beatings are every instant modified by excitations having their origin in the brain. The latter organ sends out to the ganglia of the heart two sets of nerves—the pneumogastric, or retardator, and the accelerator nerves. Excitation of the former diminishes the frequency and augments the force of the heart's movements. The accelerator nerves produce the opposite result, increasing the number and lessening the force of the heart's contractions. These two sets of nerves accommodate the activity of the heart to that of the rest of the organism, and hold it in equilibrium with the continual oscillations of the various functions of body and soul. Besides these filaments, extending from the brain to the heart, there are others from the heart to the brain, which M. Cyon calls *depressors*. The office of these nerves is to notify the brain, and consequently the soul, of the changes occurring in the rhythm and energy of the cardiac contractions. Thus, in virtue of the pneumogastric and the accelerator nerves, the heart is an organ whereon is reflected, immediately and with precision, every passional state, with its nicest shades of distinction. And, on the other hand, in virtue of the depressor-nerves, our consciousness notes the infinitely-diverse oscillations of the heart's beatings attendant on passional states. The mechanism of the heart's motions under passion depends on these two inverse nerve-currents.

Every agreeable or joyous emotion of the soul excites the accelerator nerves of the heart, and causes that organ to beat with great rapidity, lessening at the same time the force of its contractions. The phrases, *the heart leaps with joy*, or *flutters with joy*, admirably characterize this action of the accelerator nerves. The facility with which the heart drives the blood into the arteries, under such circumstances, produces that feeling of comfort and pleasure which is expressed by the words, *a light heart*. On the other hand, all sad or painful feelings act chiefly on the retardator fibres of the pneumogastric nerves. Emotions of this description diminish the rapidity of the heart's beatings, and so increase the amount of blood discharged from that organ at each diastole; hence the contractions by which it drives the blood into the vessels are laborious and protracted. These contractions, attended as they are with pain, give rise to an *ensemble* of sensations, expressed in common language by such phrases as *oppression of the heart*, *the heart is agonized*, etc. That other phrase, *the heart is ready to burst*, expresses, with great exactitude, the sensation of stricture one feels when suffering from pent-up anguish. The news of some

painful loss, when suddenly conveyed, oftentimes produces wild, irregular contractions, owing to a paralysis of the retardator nerves, and it is not rare to find this disordered excitation followed by a total stoppage of the heart's action, and syncope. Hence, says Claude Bernard, when we have to communicate to a person some *heart-breaking* piece of intelligence, we must use great precaution. The intensity of the effects produced on the heart by the soul's emotions depends, above all, on the excitability of the nerves connecting heart and brain. The greater the excitability of these nerves, the more pronounced are the heart's motions, and the finer, too, and the more delicate are the consecutive impressions. It is because the nerves of women and children are more excitable than those of men, that their hearts also are more profoundly affected by the emotions; or, in common language, their hearts are more tender, more sensitive.

While the heart seems to be more directly under the influence of the feelings, the lungs appear to have some connection with thought. When absorbed in some profound meditation, or when listening to some orator whose discourse rivets our attention, we suspend the respiratory movements. Darwin offers an ingenious explanation of this phenomenon, attributing it to the habit we have contracted of not breathing when we are listening attentively, so as not to disturb by the sound of the breath the silence necessary for catching every syllable.

From the fact that the real affections of the soul, and consequently of the brain, are always accompanied by disturbance of the respiratory and circulatory functions, we may conclude that the heart and the arterial tension are the true index of the passional states. Hence it is that the actor, when he would prove that some perilous situation inspires him with no fears, seizes the hand of the one he seeks to reassure or to convince, and places it over his own heart, in order to show that the beatings of that organ keep up their usual rhythm. Hence, too, it is that we must not regard outcries and gestures as positive indices of passion. When you see a woman weeping and agitated on hearing some painful news, you have only to feel her pulse; if that is normal, you may pronounce the emotion simulated. On the other hand, if you see a woman whose distress is manifested by no outward signs, but whose heart beats with unwonted irregularity, you may be sure that she feigns a calm that is not in her soul. There is yet another mode of ascertaining, and even of measuring accurately, the strength of emotions. This we may do by applying either to the pulse or to the heart one of those delicate apparatus invented by M. Marey, which trace on a sheet of blackened paper curves of greater or less sinuosity, representing the number, the force, and the form of the beats of the pulse, or the contractions of the heart. Just as these apparatus give us tracings which at once indicate the nature of the heart's motions in various diseases, for instance, fever, typhus, or pneu-

monia, they might in like manner give us graphic representations of its motions under the influence of the various passions, such as love, fear, grief, joy, anger, etc. Indeed, each of these states of the soul produces, in the order of the heart's beatings, a modification so peculiar and characteristic that we may regard each of the passions as having a curve of its own. M. Cyon, who has recently suggested this ingenious idea of applying graphic apparatus to the physiology of the passions, gives some illustrations of the bearings such experiments might have. Among the heirs gathered round the bed of a dying man there is one whose grief causes his heart to beat slowly but violently. In some of the others, who impatiently await the end, the heart beats quickly but feebly. The graphic apparatus, which describes, with marvelous precision, the rhythm of cardiac contractions, and which is called the *cardiograph*, could in this case exhibit the real feelings of the heirs. This is not at all an exaggeration, and we have no doubt that an instrument of great sensibility could be got to note the differences here referred to. Perhaps the case would be different under circumstances of greater complexity. The modifications of the heart's beating intervene in a twofold manner, in the determination of our inclinations and in the acts which proceed from them, either by producing sudden changes in the quantity of blood diffused through the nerve-centres, or by giving us agreeable or painful sensations through the depressor nerves. Now, a sudden afflux of blood to the brain, and extremely painful sensations, may produce, in a man not suffering from any mental disease, the craziest notions, and may betray him into the commission of the most serious offenses. Suppose a man commits a crime under circumstances but ill understood; the question arises, Was he moved to the act unconsciously and by physiological causes, or did he do it designedly and after calm reflection? M. Cyon thinks he can resolve this problem as follows: The soul possesses the faculty of experiencing, on the recollection of a past act, emotions of a like kind with those it experienced at the moment of its commission. The detailed history of a crime must produce in the accused who listens to it—supposing that he had committed the crime knowingly—emotions of this kind, as also the cardiac motions necessarily correlative to them. Hence the judge may, by means of the cardiograph, inform himself as to the presence or absence of these motions, and so decide whether the accused has or has not a recollection of the crime, i. e., has committed the crime whether with or without consciousness. This instance is rather ingenious than plausible, rather theoretic than practical. Of course, an individual who has committed a crime in a state of delirium cannot, on hearing the history of that crime, experience the same emotions, nor consequently the same modifications of the heart's movement, as he would if he had committed it with a full knowledge of what he was doing; still, it would be as hard for him in the one case as in the other, to maintain an absolute *sang-froid*. A man who is

accused of having committed a crime, and who knows that he has committed it, is alarmed at the sight of the judge who questions him, and at the thought of the accusation which stands against him, even though the crime was committed in a moment of delirium. On the other hand, it may easily happen that a hardened malefactor, who has committed a crime with full deliberation, will be so far master of himself as to feel but insignificant emotion when the circumstances of his crime are brought up before him. Yet this idea of M. Cyon's merits the attention of psychological physiologists, and we may venture to hope that the day will come when treatises on psychology will conclude their descriptions of passional states with graphic tracings showing the rhythm of heart-contractions which answers to each passion. These tracings will be trustworthy and precise, for, if the will be mistress of movements and demonstrations that appear at the surface, it has but very little power over viscera that are concealed, like the heart, and these are truthful witnesses, ever at hand to rectify lying testimony.

II.

But we must bear in mind that muscles which are subject to the will are not always employed to dissemble passion, but that very often, by their almost automatic attitude, they betray the real state of the feelings. In vain would a man in a furious passion strive to stand still. All his members are agitated with violent movements. Astonishment produces a relaxation of the muscles, and hence the French phrase, *les bras tombent* (the arms fall), to denote the effects of this emotion. Fear causes one's legs to fail him; one is said to be *petrified* by fear. But there are none of the muscles that are so influenced, so modified by the passions, as those of the face. The physiognomy is indeed a betrayer of the soul's inner states. "When the soul is agitated," says Buffon, "the face becomes a living picture, wherein the passions are given with equal delicacy and force; where every movement of the soul is expressed by a dash of the pencil, and each act by a character, the rapid, living impress of which outstrips the will, thus unveiling and manifesting, by passionate signs, our most secret emotions."

It seems impossible to subject to physiological analysis appearances so complex, so varied, and so fickle. And yet an accomplished experimenter has recently succeeded in partially ordering this chaos, and in precisely determining the muscular mechanism of the human physiognomy as related to the various passions. Having first ascertained, by minute dissections, the position and separate function of the numerous muscles situate between the skin and the facial bones, and having learned how the nerve-filaments of the *seventh pair* (the facial nerves) are distributed through these muscles and animate them, M. Duchenne, of Boulogne, has determined, by means of the electric current, or of

various excitants, the contraction of each particular one of these little muscles. Again, by observing those ready-made experiments which we call diseases, he learned what takes place when some of these muscles contract while others are inactive. In this way he has been enabled to see, most clearly, that the contraction of each muscle of the face determines a certain invariable expression; that is to say, that each passion seems to have at its command a facial muscle which contracts so soon as the soul is moved by this passion. M. Duchenne discourses as follows about the *muscle of suffering* (*souffrance*), as he calls the muscle whose contraction indicates pain. "From the very outset I had observed that the partial movement of one of the motor muscles of the eyebrow always produced a complete expression in the human face. For instance, there is one muscle which expresses pain—the superciliary muscle. On causing this to contract by electricity, not only did the eyebrow assume the form expressive of pain, but the other parts and features of the countenance, particularly the mouth and the naso-labial line, seemed also to undergo a profound modification, so as to harmonize with the eyebrow, and, like it, to give expression to this painful state of the soul." So, then, other muscles appear to share with the superciliary in the expression of suffering. M. Duchenne, however, believes that he is authorized by his experiments in holding that the muscular region of the face directly modified by a single passion is very circumscribed. But this modified region acts by a sort of sympathy on the adjacent regions precisely as one color modifies the tint of the colors all around it; and, just as, in the latter case, there is caused an optical illusion, the result of what Chevreul calls the simultaneous contrast of colors, so with the muscular movements of the face there is produced a kind of mirage which modifies, complicates, and seems to dilate a movement whose real sphere is very restricted. However this may be, M. Duchenne has succeeded in reproducing, by contractions called forth in a certain number of the facial muscles, nearly all those expressions which answer to the inner states of the soul, and he has thus been enabled to assign to each muscle a psychological in addition to its physiological name. Thus, the frontal muscle is the muscle of attention, surprise, wonder, and alarm, and each of these emotions excites it in a different way. The great zygomatic and the inferior orbicular muscles are the muscles of joy, while the pyramidal muscle of the nose is the muscle of aggression, and so on. In general, the muscles of the eye are adapted to expressions of the higher order, and those of the mouth to expressions of a more gross and material kind. The purely self-satisfied and sensual smile calls into play only the zygomatic muscle. It is the contraction of the inferior orbicular that gives to the expression of contentment and pleasure a character of good-nature and benevolence. Besides the primary expressions resulting directly from the play of one muscle, M. Duchenne finds that several

passional states of the physiognomy may be resolved into a number of simple movements.

And, just as he produces simple passional expressions by artificial means, so, too, he effects the synthesis of the complex expressions. *Attention*, which is produced by the contraction of the frontal muscle, and *joy*, which is due to the conjoint activity of the great zygomatic and the inferior orbicular, are primary expressions. Whenever we determine simultaneously on one face the contraction of these two muscles, we get the physiognomy of a person who has a lively impression of some pleasing and unexpected news. If, together with these muscles, we excite that which serves to express lechery—i. e., the transverse nasal muscle—we get the type of *attention directed toward some lascivious object.* If we associate the lines indicating pleasure with those denoting pain, we recognize at once the melancholy smile. When we combine the smile (by contracting the great zygomatic) with gentle grief (by contracting the minor zygomatic), or, better still, with a slight contraction of the muscle of suffering—the superciliary—we have an admirable and touching expression of pity and compassion.

These fine physiological dissections, and the masterly syntheses they suggested to M. Duchenne, are nearly in full accord, as concerns their results, with the most ancient observations of empiricism, with the intuitions of painters and sculptors, as also with the teaching of psychologists and moralists. Results of this kind add nothing to our knowledge of the body or of the mind, but they will, perhaps, be of service to artists who desire to be exact in the anatomical reproduction of the passional movements of the physiognomy. No doubt the genius of superior artists is a sure and potent instinct, which leads them to follow rules they know not; and it is probable that neither Raffaelle, nor Correggio, nor Titian, would have been a greater painter, had he known, as modern physicists do, the laws of harmony and the simultaneous contrast of colors. Nevertheless, this sure and potent instinct, the germ of which exists in the *élite* of the artist-world, may be to some extent acquired by laborious study, and hence the conscientious artist will understand all the advantage to be derived from a science which, by giving him precise and certain directions, will save him much preliminary labor and much fruitless experiment.

Why is one special muscle of the face affected by pain, another by fear, and a third by anger? In short, why is every passion interpreted in the physiognomy by regular, determinate movements, just as the rhythm of the heart is modified? To give the question a more general form, is there a logical relation between gesture and emotion? This is a difficult question, recently put by Mr. Darwin, and which he strives to answer in accordance with his usual doctrines. For him, instincts are habits originally acquired purposely, voluntarily, and afterward fixed in the race by heredity. The instinctive movements of the physiognomy, considered as passional ex-

pressions, have the same origin. Thus, the habit of praying with the hands joined palm to palm comes, according to him, from the fact that in past times captives testified their entire submission by holding up their hands to be bound by the victor. The captive assumed the kneeling posture, in order to make this operation easier. Thus, the gesture and the attitude, which are now the instinctive expression of adoration, of devotion, would be merely vestiges of the savage usages of primitive man. When we are angry with a person, we involuntarily close our fists, so that they may be ready for use, even when we have no intention of striking the one who has angered us. If, under the action of similar feelings, the lips contract so as to show the teeth, as though we were preparing to bite, the reason is, says Darwin, that we are descended from animals who used their teeth as weapons of offense. Why do the eyebrows assume an oblique position when a person is suffering pain? For this reason: when children cry from hunger or from pain, the act of crying profoundly modifies the circulation; the blood flows to the head, and particularly to the eyes, and this produces an unpleasant sensation. The muscles around the eyes then contract so as to protect them, and this action has become, under the influence of selection and heredity, an instinctive habit.

Most of Mr. Darwin's ingenious explanations thus tend to refer movements of the physiognomy, that are now involuntary and instinctive, to movements that once were voluntary and intentional. Many of these explanations seem plausible, but it is nevertheless true that the physiognomy betrays the emotions and passions by means of signs entirely independent of the will. That some of the muscular movements of the face arose in the manner described by Darwin we might admit, but still we cannot see how that accomplished naturalist can reduce under his fundamental hypothesis those complex movements which are expressed by laughter, lachrymal secretion, blushing, pallor, turgescence or flaccidity of the flesh, and the flashing and dimming of the eyes. All these phenomena are entirely independent of the will, nor can they be explained on the theory put forward by Darwin to account for the eyebrow contracting under the influence of painful emotions, or for the lips contracting in anger. Therefore, we are forced to the conclusion that the agitation of the cephalic centres, produced by the passions, calls forth, in virtue of the anatomical relations of those centres with the facial nerves and muscles, reflex phenomena that never were under the control of the will. The habit of seeing such and such an expression associated with such and such a passion leads us to judge of the one by the other; but yet the habit is not the efficient cause of the expression.

There still remains to be considered one more series of physiological phenomena which bear the impress of passion, viz., vocal phenomena. The inflections of the voice, as related to the passions, are as varied as the expressions of the physiognomy. Each passion has its

own language, its own tones, its own note, just as it has its own nerve and its own muscle. Physiological analysis, however, is far more difficult here than in the case of the physiognomy. How shall we analyze the complex mechanisms that cause the lungs and the larynx to produce the various sounds of moaning, crying, groaning, sobbing, and sighing? We are acquainted with the *ensemble* of muscular functions which give rise to these different expressions of the soul's states, but why does laughter express gayety, and sighing express sadness? We cannot tell.

To sum up: a profound disturbance of the circulatory and respiratory acts; a more or less violent agitation of the members; changes of the attitude of the body; diversified movements in the physiognomy; infinitely-varied inflections and modulations of the voice—all these phenomena are the consequence of what takes place in the brain when that organ receives impressions of such a nature as to agitate it.

Hence we see that the main-spring of passion is the sense-impression. But what is this impression? In order to answer this question, let us analyze some passional state. We shall there find four principal elements: a more or less distinct initial sensation of pleasure or pain; voluntary or involuntary movements, more or less pronounced; and, finally, a recurrent sensation consecutive to these movements. It is clear that if there were no sensation there would be no passion. On the other hand, if the sensation were but a motion, we might say that passion consists of a series of motions originating in the agitation of the sensorium produced by the internal or external causes of emotion; but, then, we never could understand why this agitation, being purely vibratory, should affect us at one time agreeably, at another painfully, or why it should act in so many different modes. Hence the power of discerning, immediately, in the sensorial perception, differences that have no mechanical equivalent, cannot be explained on mechanical grounds, and it is absolutely necessary to recognize here a psychic faculty, whose function it is to ascertain and to conceive the causes of emotions, and to regulate, according to a certain harmony, the consecutive physiological movements. Passion, therefore, resides in a something that is neither the brain, nor the nerves, nor the muscles; a something which perceives, and joys, and suffers, and which moves the entire body in unison with its own feelings. Now, this conscious faculty, this faculty of perceiving causes in no wise mechanical, is the soul. The more deeply we study the physiology of the passions, the more are we convinced that the agitation of the nervous and motor energies is but the external manifestation of deeper causes, which we denominate psychic. So, too, the more we study into matter, the better we see that it is only an external form, a vesture that clothes the activity of an invisible principle. Thus does Science ever lead us back to that eternal and mysterious thing, force, and, beyond force, to spirit.—*Revue des Deux Mondes.*

OUR ANCESTORS ON THE GOOSE QUESTION.

LET us consider the views entertained by our ancestors for centuries on the goose question: we may gather lessons from it that will be very applicable to-day. They believed for five hundred years that a certain kind of goose was of vegetable origin, and grew on trees. The story is ancient and obscure, and much ingenuity has been spent in explaining it. Without attempting to reconcile its contradictions, or account for its origin, we will only here give a brief outline of the tradition.

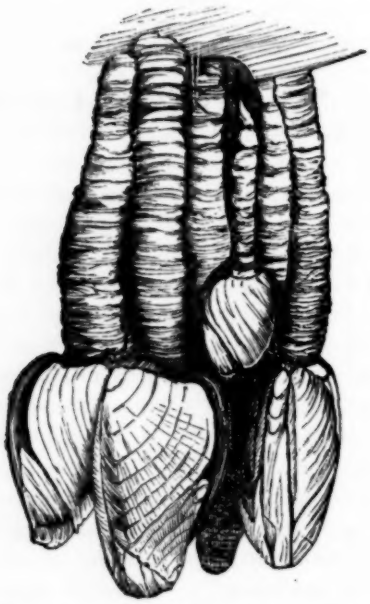
Belonging to that division of the animal kingdom known as articulates or jointed animals, there is a class called crustaceans, from the crust-like shell with which the body and legs are covered, and of which lobsters, crabs, and shrimps, are examples. Among these is a group known as "Cirripedia," from the *cirri*, or curls of hair, in which their long and slender feet terminate. They are inclosed in a more or less conical shell, and some of them are pedunculated; that is, their main body hangs from a stalk, pedicle, or peduncle, of varying length, which permits of some degree of motion. They attach themselves to floating objects, as plank, worm-eaten fragments of wreck, ships' sides, and sometimes to the cuticle of the whale. These creatures are more familiarly known as barnacles, and Fig. 1 represents a pendent group of common ship-barnacles, which are described as having "a flesh-colored, translucent, wrinkled stem, possibly more than a foot long, and from this stem there dangles a triangular, pearly-shelled fish, the valves of which, bordered with the most lovely orange, from time to time open and disclose several pairs of curling feelers." The soft part within this shell, in old times, used to be mistaken for a little bird.

There is in England a well-known species of goose called the barnacle-goose. "It is a winter migrant on the east coast; its summer home, where it breeds, being the high latitudes of Northern Europe. It is a very handsome species, a vegetable-feeder, and excellent eating." Now, it would seem to be a very simple matter to end the story by saying that it was long believed that barnacle-geese had their origin in the barnacle-shells we have just referred to, but the case is more complex; the shells bearing the geese were believed to grow on trees. This belief, that the barnacle-shell is transformed into the barnacle-goose, was well established, as early as the twelfth and thirteenth centuries, and was referred to and contradicted by both Albertus Magnus and by Roger Bacon. That the opinion was held as a firm reality is sufficiently proved by the fact that barnacle-geese were allowed to be eaten during Lent, under the idea that they were not fowl, but fish—an elastic zoology that served to widen ecclesiastical dietetics, although to the scandal of the more strict, as the practice

was inveighed against with great unction by Sir Giraldus Cambrensis, who treated the subject, in the twelfth century, in his "Topographia Hiberniæ." Michel Drayton refers to it, in his "Polyolbion:"

> "The barnacles with them, which, wheresoe'er they breed—
> On trees or rotten ships—yet to my fens for feed
> Continually they come, and chief abode do make,
> And very hardly forced my plenty to forsake."

Fig. 1.



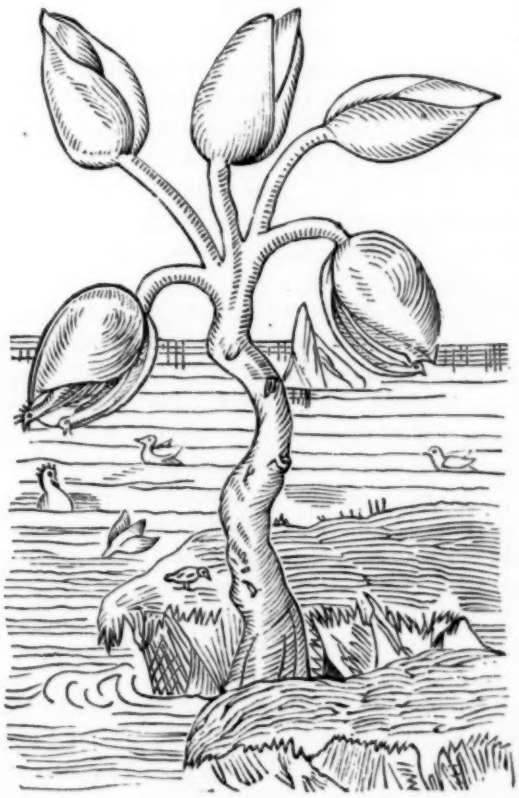
Lepas Anatifera—Common Ship-Barnacles.

Baptista Porta refers to it, about the year 1500, and Count Meyer devoted a volume to it—"Volucris Arborea." The earliest published statement, *by an eye-witness*, is contained in the "Cosmograph and Description of Albion," of Hector Boëce, while the earliest pictorial illustration of the goose-tree, and its animal fruiting, is contained in the "Cosmographia Universalis" of Sebastian Munster, printed at Basel, 1572.

In the middle of the sixteenth century, Turner, the English ornithologist, wrote as follows: "Nobody has ever seen the nest or egg of the barnacle; nor is this marvelous, inasmuch as it is without parents, and is spontaneously generated in the following manner: When, at a certain time, an old ship, a plank, or a pine mast rots in the sea, something like fungus at first breaks out thereupon, which at length puts on the manifest form of birds. Afterward, these are clothed with feathers, and at last become living and flying fowl. Should this ap-

pear to any one to be fabulous, we might adduce the testimony not only of the whole people who dwell on the coasts of England, Ireland, and Scotland, but also that of the illustrious historiographer Gyraldus, who has written so eloquently of the history of Ireland, that the barnacles are produced in no other way. But since it is not very safe to trust to popular reports, and as I was, considering the singularity of

FIG. 2.



THE GOOSE-TREE.

"They spawne, as it were, in March and Aprill; the Geese are found in Male and June, and come to fulnesse of feathers in the moneth after. And thus hauing, through God's assistance, discoursed somewhat at large of Grasses, Herbes, Shrubs, Trees, Mosses, and certaine excrescences of the earth, with other things moe incident to the Historie thereof, we conclude and ende our present volume, with this woonder of England. For which God's name be euer honoured and praised."—(GERARDE, "Herball," 1633.)

the thing, rather skeptical even with respect to the testimony of Gyraldus—while I was thinking over the subject—I consulted Octavian, an Irish clergyman, whose strict integrity gave me the utmost confidence in him, as to whether he considered Gyraldus worthy to be trusted in what he had written. This clergyman then professed himself ready to take his oath upon the Gospels, that what Gyraldus had

recorded of the generation of this bird was most true; for he himself had seen with his eyes, and also handled those half-formed birds; and he said further that, if I remained a couple of months longer in London, he would have some sent to me."—(TURNER'S "Avium Præcip. Hist.," art. "Anser.")

But the writer to whom we are most indebted for authentic information upon this interesting subect is Gerarde, the father of English botany, and author of the "Herbal," a ponderous work of 1,500 pages, from which the cut Fig. 2 is taken. He says: "What our eyes have seen, and hands have touched, we shall declare. There is a small island in Lancashire, called the Pile of Flounders, wherein are found broken pieces of old and bruised ships, some whereof have been cast thither by shipwreck, and also the trunks and bodies, with the branches, of old and rotten trees, cast up there likewise; whereon is found a certain spume, or froth, that in time breedeth unto certain shells, in shape like those of the mussel, but sharper pointed, and of a whitish color, wherein is contained a thing in form like a lace of silk finely woven, as it were, together, of a whitish color; one end whereof is fastened unto the inside of the shell, even as the fish of oysters and mussels are; the other end is made fast unto the belly of a rude mass or lump, which in time cometh to the shape and form of a bird. When it is perfectly formed the shell gapeth wide open, and the first thing that appeareth is the aforesaid lace or string; next come the legs of the bird hanging out, and as it groweth greater it openeth the shell by degrees, till at length it has all come forth, and hangeth only by the bill. In short space after it cometh to full maturity, and falleth into the sea, where it gathereth feathers, and groweth to a fowl bigger than a mallard and lesser than a goose, having black legs, and bill or beak, and feathers black and white, spotted in such manner as our magpie, called in some places pie-annet, which the people of Lancashire call by no other name than tree-goose; which place aforesaid, and of all those places adjoining, do so much abound therewith, that one of the best is bought for threepence. For the truth thereof, if any doubt, may it please them to repair to me, and I shall satisfy them by the testimony of good witnesses."

Again says Gerarde: "The historie whereof to set foorth according to the woorthiness and raritie thereof, woulde not onely require a large and peculiar volume, but also a deeper search into the bowels of Nature than my intended purpose wil suffer me to wade into, my insufficiencie also considered, leaving the historie thereof rough-hewen unto some excellent men, learned in the secrets of Nature, to be both fined and refined; in the mean space take it as it falleth out, the naked and bare truth, though unpolished."

When the Royal Society of England had been established fifteen years, this fable was accepted, and described in the philosophic transactions, in 1677, by Sir Robert Murray, who says: "Being on the

island of Uist (East) I saw lying upon the shore a cut of a large fir-tree, about two and half feet in diameter, and nine or ten feet long, which had lain so long out of the water that it was very dry, and most of the shells that had formerly covered it were worn or rubbed off. Only on the parts that lay next the ground there still hung multitudes of little shells. This barnacle-shell is thin about the edges, and about half as thick as broad. Every one of the shells has some cross-seams or sections, which, as I remember, divide it into five parts. These parts are fastened one to another with such a film as mussel-shells have. These shells are hung at the tree by a neck, longer than the shell, of a kind of filmy substance, round and hollow, and curved not unlike the windpipe of a chicken, spreading out broader to where it is fastened to the tree, from which it seems to draw and convey the matter which serves for the growth and vegetation of the shell and little bird within it. In every shell that I opened I found a perfect sea-fowl: the little bill, like that of a goose, the eyes marked, the head, neck, breast, wings, tail, and feet formed; the feathers everywhere perfectly shaped, and blackish-colored; and the feet like those of other water-fowl, to my best remembrance."

Many conjectures have been offered as to the origin of this strange myth, and Max Müller suggests the hypothesis that it came from the early misapplication of terms. He remarks: "No man would have suspected Linnæus of having shared the vulgar error, nevertheless he retained the name *Anatifera*, or duck-bearing, as given to the shell, and that of *Bernicula*, as given to the goose."

ALTERNATIONS IN THE INTENSITY OF DISEASES.

FROM THE FRENCH OF ALPHONSE DE CANDOLLE.

TRANSLATED BY H. H. W.

THE diminution of the efficacy of vaccination, as a preservative from the small-pox, has been the subject, at first of incredulity, and afterward of surprise, to the medical world, and even to the non-professional public. The causes of this change have been sought in the nature of the vaccine matter. But it has not been demonstrated that taking the matter anew from the cow is to restore the primitive efficacy of the remedy.

Without wishing to call in question with the profession the chances of discovering an explanation, drawn from the domain of medical and physiological facts which they occupy, I desire to point out a consequence of the fundamental law of heredity, as applied to the phenomenon in question. In order to understand the subject in its true

aspects, it will be well, in the first place, to recall a fact in relation to epidemics.

Medical history proves, on the subject of epidemic and contagious maladies, a marked fatality at the time of their first appearance, followed by slowly-decreasing violence from generation to generation. In our own memory the epidemic visits of cholera have diminished in frequency and intensity within a short period of time. Previously to our day, syphilis and varioloid, two infective diseases, differing in their nature, and in their modes of transmission, had presented the same phenomenon—Extreme intensity at the beginning, diminution from period to period.

If this diminution belonged to the nature of the maladies, populations infected for the first time in the nineteenth century should have suffered less than those infected in previous centuries. But this is not what has occurred. When a savage population has recently been visited, for the first time, by the infection of small-pox, it has suffered as much as the Europeans at the beginning of the malady in Europe. It is the fact of invading a new field which renders epidemics destructive. Upon a little reflection, the reason of this is easy to comprehend.

When an epidemic falls upon a population for the first time, the greater part of the individuals disposed to receive the disease are attacked. They die in great numbers. Subsequent births are the offspring of persons who did not contract the disease, or, at the least, who contracted, yet survived it; that is to say, of persons better constituted than others to resist the disease. By virtue of the ordinary resemblance of children to their parents, the new generation will be less disposed to suffer from the epidemic. There will be then a diminution of the violence of the disease, or a temporary disappearance. For the most part I presume a *diminution*, because that the resemblance of children to their grandparents (which is called atavism) is not very rare, and tends to reproduce certain forms or physiological conditions in families. At the end of two or three generations, that special cause for the return of the epidemic is less felt, the resemblance to a great-grandfather, or ancestor still more removed, being more rare than the resemblance to a grandfather. But then the bulk of the population will no more have been exposed, by itself, or by its fathers and mothers, to the malady in question, or will have been but slightly exposed. Thus is constituted anew, by the very purity of the disease, a proportion of individuals who have not been submitted to the proof of the infection, or of whom the parents have not been submitted to the test; a proportion on whom the malady will be severe, and among whom the law of selection will recommence to operate.

The law of events (*force des choses*) introduces then a variation in the intensity of every disease, except that it does not act upon diseases of which people rarely die, or which fall principally upon the

aged. The more fatal a disease among youth, the quicker is the work of the law of selection, and the more prompt the diminution of the malady. If a first invasion, for instance, destroys a moiety of the population below marriageable age, the survivors should be very little liable, in their physical or physiological conditions, to the disease, and the children born to them will profit by their immunity. If the disease is less fatal, the purification will be less. We thus discover, I do not say *the* cause, but a cause why pestilences and other very serious maladies attack populations at intervals, and are, as it is said, epidemic; while certain diseases less serious, even among maladies which attack youth, rule from year to year in a mode more continuous.

Such are the clear laws—one might add the rigid laws—which rule in diseases, to produce aggravation or diminution, independently of all these natural circumstances. Without doubt there may be other circumstances, physical or physiological, and physicians may discover preventive or curative means which exert influence upon them. But the incessant effect of heredity, and of the law of selection, exists, notwithstanding; and, when other influences cannot be demonstrated, we may be assured that heredity and selection perform their part.

We now see that the efficacy of preventive means, such as vaccination, should also vary. When Jenner discovered the utility of vaccination, the small-pox had in a slight degree lost, in Europe, its primitive intensity. The people who then existed proceeded from many generations which could, thanks to the process of selection, passably resist the epidemic. Individuals were not so readily affected as at the origin of the disease, or, if they had the disease, they succumbed to it in a smaller proportion; or, yet again, those who survived rarely contracted the disease a second time. It was supposed that those who had the disease by inoculation were sheltered from a repetition, and the dangerous practice of inoculation would not have continued, but for this opinion. Vaccination, then, came at an epoch when the European population found itself in ameliorated conditions with regard to epidemic small-pox. Practised with ardor, it had the effect to render small-pox very rare. But, precisely because it had become rare in the generation which immediately succeeded Jenner, in the generation which issued from that was found a majority composed of persons who had not been exposed to the epidemic. Among them must have been some persons who naturally, or by atavism, were disposed to take the infection. From that cause arose a certain renewed sensitiveness (*recrudescence*), which vaccination could less easily control.

In other words, after two or three vaccinated generations, the European population having been slightly exposed to the small-pox, found itself approximating to the conditions of a population in which the disease appears for the first time. The attack is not altogether so

violent, but the return is evident. All means of resisting it, which would have sufficed fifty years since, have become less efficacious.

To sum all in general terms: heredity and selection must produce an alternation of intensity and relief in diseases. That variation must be more marked, when the disease in which it takes place is more fatal, and especially when it attacks youth. Curative or preventive means, which are sufficient in periods of light visitation, lose a portion of their efficacy at the aggravated periods. And this rule applies particularly to the use of vaccine as a preventive of small-pox.

The works of Darwin being now familiar to physicians, it is probable that many among them have considered the effect of the law of selection upon the variation of intensity in maladies. I doubt, however, whether they have given attention to the consequences relative to vaccination. It is this which has led me to bring within the range of medical investigation an application (perhaps novel) of the ideas of the celebrated English naturalist.

MODERN OPTICS AND PAINTING.

By O. N. ROOD,
PROFESSOR OF PHYSICS IN COLUMBIA COLLEGE.

II.

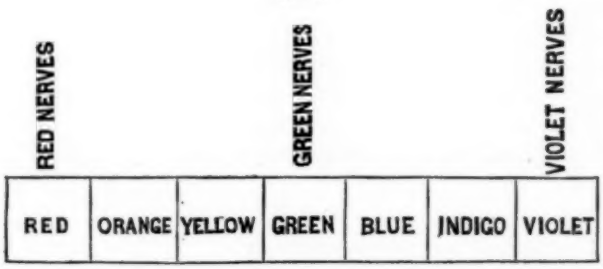
LET us now pass to the examination of a theory which was proposed in 1807 by the now justly-celebrated Thomas Young who seems to have been gifted with a scientific insight much too keen for the age in which he lived. His views being opposed to the common notions of the day, commanded but little attention, and it was reserved for Helmholtz, almost half a century later, to call attention to this nearly-forgotten theory, and to show that it accounted for all the ascertained facts in a most satisfactory manner. In this work he has been ably seconded by Maxwell, and more lately by the German physicist J. J. Müller, who with improved apparatus carefully repeated Helmholtz's original experiments, and corrected them in some minor details.

According to our new theory, then, there are in the retina of the eye, where the pictures of external objects fall, *three* sets of nerves, adapted for the production of three separate, distinct sensations, which we call red, green, and violet. When, owing to any cause whatever, one of these sets of nerves is excited into action, the result is the corresponding sensation; if, for example, we act upon the last set by electricity, pressure, or by the luminous waves, the result will be the sensation of seeing violet light, even though not a ray of light of any

kind has actually reached the eye. I think you will admit that the theory is modest in demanding only three sets of nerves, for in the ear, as it seems, there are three thousand nerve-fibrils for the perception of the separate notes. In the eye it would not have been practicable to have employed a separate nerve-fibril for each different tint, for a reason which a moment's thought will render manifest.

But to resume: according to our theory, the first set of nerves responds powerfully to the action of the longer waves, or to that kind of light which we call red; the second set is arranged for waves of medium length, it is strongly set in action by what we call green light; and, finally, the third set is stimulated into action by the shortest waves, or by violet light. Let us for the present call them the red, green, and violet nerves. This diagram shows their relation to the colors of the spectrum (*see* Fig. 1). As I have just intimated,

Fig. 1.



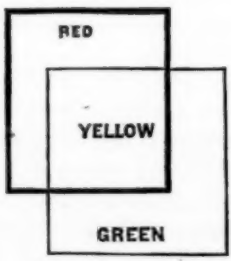
these nerves can be set into action by electricity or pressure, and other causes besides light. Taking this into consideration, the next point in the theory will not seem so singular to you: it is, that each set of nerves is capable of being acted on, to a lesser extent, by waves of light not properly belonging to it; so, for example, the set adapted for green light can, to some extent, be stimulated by red light. In a case like this, the sensation will still remain that which we call green, though actually produced by red light. The theory demands this, and the results of experiments on persons who are color-blind to red light are in accordance with it, and presently I hope to give some experimental illustrations of it. The red and violet nerves also have this property, and can be partially set into action by light which does not belong to them, but in each case the sensation remains the one that properly appertains to them.

The last point of the theory is, that, when by any cause all three sets of nerves are excited into action with about the same intensity, the resulting sensation is that which we call white.

We are now in a condition to take up the explanation of the sensations which we call yellow, orange, and blue. Let us suppose for a moment that the eye is acted upon by waves of light shorter

than those that produce the sensation of red, but longer than those that give us that of green; referring to Fig. 1, we see that no especial set of nerves has been provided for this case, but a moment's reflection will suggest that these intermediate waves, according to our theory, ought to set into moderate action both the red and green nerves, that the stimulation of the former should predominate as the length of our intermediate waves is made longer; the green set, on the other hand, coming more into play as it is shortened. This accounts, then, for the mode in which waves of a certain length, or light of a certain kind, gives us the sensation of yellow or orange. The light may be simple, and of only one kind, but it produces a compound sensation, made up of the two simple sensations, red and green. From all this it follows that, on the other hand, if we actually present to the same eye mixtures of red and green light, the sensations of yellow or orange ought, according to our theory, to be produced. This is a matter that we can easily test by experiment. With the same apparatus used a moment ago for combining blue and yellow light, I throw upon the screen a large square of red light, and superimpose on it one of green, and, as you see, the result is a fair yellow; on reducing the brightness of the green component, the yellow passes into orange (Fig. 2). I call your attention, in passing, to the circumstance

Fig. 2.



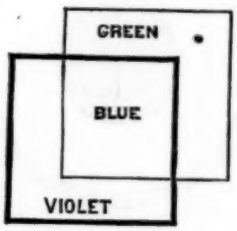
that, according to the old theory, the result ought not to have been yellow, but rather an approach to white, all the colors, according to its doctrines, being present. Restoring the green squares to their original brightness, and reducing the intensity of the red light, we easily obtain a greenish yellow, completing thus this series of tints.

And now to account for the blue: pure blue light has a wave-length intermediate between that of green and violet light, and hence sets both the green and violet nerves into action, and, though the light itself may be simple, it produces a compound sensation which we call blue. Corresponding to this, I ought to be able to reproduce on the screen blue light by mixing together green and violet light. The experiment is now arranged, and, as you see, we actually do obtain a quite good blue in this way, and can cause it to run through all

the changes from greenish blue to violet blue, by altering the intensity of the original components (Fig. 3).

It is easy for us now to understand why, in what I some time ago called our fundamental experiment, yellow and blue light, when mingled, gave not green, but white light; the yellow light stimulated into action the red and green nerves, the blue light the green and violet ones; thus, all three sets of nerves being called into play, the result was of course the sensation of white.

FIG. 3.



As it will be desirable hereafter to mingle light by the method of revolving disks, it may be well at this point to repeat our fundamental experiment after this fashion, so as to be assured of the correctness of this mode of experimenting. I have placed in front of the lantern a small circular card-board disk, provided with openings over which are fastened pieces of yellow and blue glass (Fig. 4); its

FIG. 4.

magnified image now covers pretty much the whole screen, and, on causing it to revolve, the colors as you see vanish, and we have in their place a broad circular band of white light (Fig. 5). With a concave mirror, I throw beside it on the screen a direct beam of white light from the lantern, and, if there is any difference, it is in the light from the disk being a little whiter than that of the lantern. The method with revolving disks gives, then, the same result with the more direct one formerly applied, and we can now very conveniently use it for a final test of the new and old theories. Here is

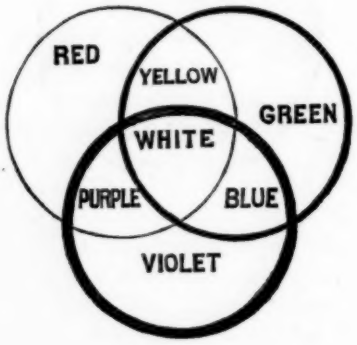
a disk cut like the last with open spaces, and armed with red, yellow, and blue glasses. You can predict the result beforehand: it must be white light with added red light—and, as you see, we actually do obtain a broad circular band of red light. Replacing this disk by one provided with glasses capable of transmitting red, green,

FIG. 5.

and violet light, we find that their mixture actually gives us white light. In all these experiments we have been content with the colored light furnished by stained glasses, but Helmholtz has pushed the investigation much further, and has obtained corresponding results by the use of the pure colored rays of the spectrum.

I called your attention some time ago to the typical mode of expressing the old theory by three intersecting circles of red, yellow, and blue; we have now again on the screen three intersecting circles; the colors are red, green, and violet, with white at the centre

FIG. 6.

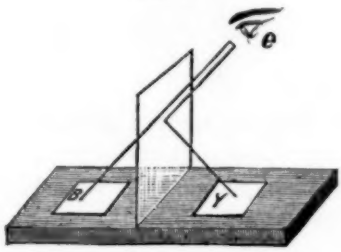


(Fig. 6). It expresses in a condensed form some of the main points of the theory of Young and Helmholtz, and gives us at the same time some of the chief laws of Nature's palette, showing, in a kind of short-hand way, the changes which the tints of surfaces undergo

when exposed to a double illumination, or when illuminated by light having a hue different from that of the surface itself. Applications of it will be given at a later stage.

Before leaving this part of the subject, I wish to show a very simple apparatus, with which you can easily repeat for yourselves many of the experiments made to-night, as well as add greatly to their number. It consists merely of a plate of window-glass, of good quality, set up on edge, and fastened on a blackened board (Fig. 7). If the

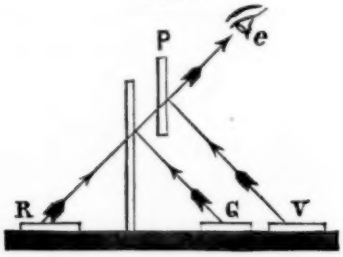
FIG. 7.



eye is placed at *e*, light will come to it directly from the blue square of paper, *B*, but also at the same time light will reach it from the yellow square of paper, *Y*; and these two masses of colored light, being mingled on the retina of the eye, will produce the same effects which I have just exhibited to you with much more costly apparatus. You will also find that you can vary the brightness of either of your squares by adjusting them at a greater or less distance from the plate of glass. When they are near to it, the yellow will predominate; the blue, when they are farther from it. Great use was made by Helmholtz of this contrivance in his experiments on this subject, and you will easily be able to prove for yourselves that the red light from paper painted with vermilion, when combined with the green light from the water-colored pigment known as "emerald-green," gives a yellowish or orange tint, according as the apparatus is arranged. Chrome-yellow (the pale variety) and ultramarine-blue give an excellent white. It is somewhat difficult to obtain a good representative of violet from among the colors in use by artists. I find that some samples of the dyeing material known as "Hoffmann's violet BB" answer better than any of the ordinary pigments. If a deep tint of its alcoholic solution be spread over paper, and combined in the instrument with emerald-green, a blue, greenish-blue, or violet-blue, can be readily produced. It is evident that a multitude of experiments of this character can be made, the number of colors united at one time being limited to two. For certain purposes I have modified the apparatus so that three tints can be combined. A second plate of glass is added at *P*, Fig. 8; this allows the compound beam of light from the first

plate to pass, but in addition it reflects to the eye a beam of light from a third slip of colored paper at *V;* and, by revolving the second glass plate slightly, the intensity of the third beam is easily regulated. This arrangement can be used to produce white light, by the mixture of three colors, for example, vermilion, emerald-green, and the violet just mentioned.

FIG. 8.

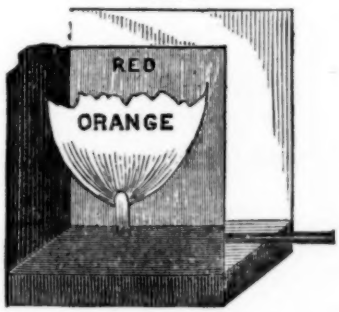


Let us pass, in the next place, to the consideration of another class of facts, which have an important bearing on our subject. If you illuminate some such object as a sheet of paper with a very moderate light, then, upon doubling the amount of light falling on it, it is possible that the paper, in the second case, may appear to you twice as bright as it did at first. But, if this process be for some time continued, you will soon come to a point where doubling the actual illumination produces very little effect, and finally a stage will be reached where a very great increase of actual illumination produces no additional effect on the eye at all, your paper looking no brighter than in a much feebler light. Let me make an experiment, to at least partially illustrate this: We have now upon the screen four large squares of white light, and they are, as you see, all of equal brightness. But, by turning this Iceland-spar prism, I superimpose one of the squares upon its neighbor; the central square now seems rather brighter than its companions, but I think no one in this room would suspect that its actual illumination was *twice* as great as that of the others. To take a still more striking example out of your own experience: you have often noticed the reflection of the gas-flames in the streets against the four panes of glass used to protect them, and have seen that the real flame looks brighter than the reflected one; but who would suppose that its actual luminosity was more than eleven times greater than that of its companion? In point of fact, sensation does not, for the most part, increase as rapidly as the actual intensity of the light exciting it, and a point can finally be reached where sensation does not increase at all, even though the actual brightness of the light is greatly multiplied. Our nervous organization is, in this direction, limited and finite, just as it is in all others.

The next matter to which your attention is called is really allied

to the preceding, though, at first sight, the connection is not very evident. Any color, if very luminous, seems paler than it really is. This simple piece of apparatus, where a bat-wing gas-flame is placed between a sheet of card-board and a plate of stained glass, will serve for experimental demonstration. The glass is red, and the paper seen through it appears of a deep-red hue, but the gas-flame itself, being much more luminous than the paper, does not look red at all; its tint is orange (Fig. 9). Replacing the red glass by green,

FIG. 9.



we have the paper appearing with a deep-green hue, while the flame seems greenish-yellow. Let us see if we can explain these curious changes of tint by Young's theory. The red glass used in the first experiment transmits to the eye only red light, or light capable of stimulating mainly the red nerves; but, if we increase its intensity beyond a certain point, its action on the red nerves begins to flag, and we soon have a state of things where a further increase of the red light produces no effect at all on the red nerves, they being already stimulated up to the maximum point. But, according to our theory, this red light has all along been acting, to some extent, on the green, and to a less extent on the violet nerves; and, as we add to its intensity, it acts still more powerfully on them, so that especially the green nerves come more and more into play, and a green is added to the original red sensations; the result, of course, is the sensation of orange.

The explanation of the tint obtained in the other experiment is quite similar. The green nerves are first stimulated up to their maximum point by green light of a certain strength, a further increase of its intensity brings into play the other two sets of nerves, particularly the red, and the tint quite naturally becomes greenish-yellow. You remember that, in a previous experiment, we found that a mixture of much green with a little red light gave a greenish-yellow. The nerves for violet light always lag behind the others, as will afterward be shown by a particular experiment.

The general effect, then, of a very bright illumination on natural objects is to cause their colors to appear paler than they otherwise

would. This is, indeed, to the painter, a precious resource, for representing, in his pictures, high degrees of luminosity, and is often employed with most happy effect. According to the careful experiments by Aubert, white paper is only fifty-seven times lighter than black paper, and the painter is in the predicament of being obliged to represent the vast range of natural illumination within these very narrow limits; hence the desirability of employing an artifice of this kind to overcome a difficulty which, if fairly met, would prove insuperable.

The considerations that I have just presented explain to us, quite readily, the curious circumstance that light of any color, if very bright, is at last accepted by the eye for white, all three sets of nerves finally reaching, in the order indicated, their point of maximum stimulation. You can repeat for yourselves a simple experiment of Helmholtz's, in this connection: hold before the eyes, for some little time, a plate of stained glass; the color may be red, yellow, blue, or green; after a while you will come to consider the brightest objects in your field of view white; as, for example, a gas-flame, the sky, or white paper. In point of fact, to be quite frank, white is only a relative sensation, and, if any thing like equality of stimulation is produced in the three sets of nerves, we finally accept the tint for white. I have especially arranged an experiment to illustrate this point: We have now upon the screen two large squares of light; one is deep red, the other green: I remove from the lantern a large plate of green glass; the red square has retained its color, and is now brighter, but the other square has become white or almost white. On removing the red glass, the red square on the screen is replaced by a white one, and we now for the first time see that its companion, which a moment ago we were ready to take for white, has a decidedly green hue; in fact, all the while the light producing it has been passing through a plate of pale-green glass, which was behind the others. Let me take away this plate, and now at last we have both our squares illuminated with pure white light. Is this light really white? Not at all; it has been tinged decidedly yellow, by passing through a pale-yellow glass, which has been concealed in the apparatus all the time as a reserve, and, on removing this glass, we find that the light we were ready to accept for white looks yellow, when compared with the purer light of the lantern. Finally, if we could throw a sample of daylight on the screen, we should again see that the light of the lantern itself is not white, but yellowish. White is evidently only a relative sensation.

In some of the preceding experiments it has been seen that, as we increase the actual brightness of any colored light, red for example, so does the sensation produced also increase, but usually at a slower rate. Now, it happens that some of the sensations increase more rapidly than others; for example, the sensation for red or yellow increases

more rapidly than that for blue or violet. In fact, as I said some time ago, the violet nerves always lag behind. From this it happens that, if we place side by side a quantity of blue and red light, arranging matters meanwhile so that they appear to the eye to be of equal brightness, then, upon adding considerably but equally to their actual luminosity, it will turn out that the red light will quite outstrip in apparent brilliancy its rival. We have now two such squares of red and blue, side by side on the screen, and it is difficult to say which is the brighter; but, when I greatly increase their illumination, it becomes evident that the blue one has been beaten; or, better still, when I reverse the experiment, starting with red and blue squares, of equal and considerable brilliancy, then, upon turning down the light of the lantern, and rendering them both dark, the blue square remains visible after its red companion has vanished. As another example, I may mention the blue color of the sky, which still continues plainly perceptible at night, when the illumination is so feeble that other colors have disappeared. Dove has pointed out that, in picture-galleries, as the light of day fades out, the blue colors in draperies and skies retain their power longer than the reds and yellows.

It is owing to this circumstance that, in actual landscapes, seen under the comparatively feeble light of the moon, there is a prevailing tendency to blueness. This also explains the circumstance that a landscape, illuminated by bright white clouds, appears more yellow in general hue than when the clouds are not bright, though still retaining their whiteness, the strong white light stimulating more powerfully the sets of nerves concerned in the production of yellow. I think we all know that, on dark, dull days, there seems to be a tendency to blueness in the coloring, even though we may not have paid much attention to the reverse phenomenon. All this is prettily illustrated by a very simple experiment of Helmholtz's, who noticed that the impression of a bright day was produced by merely holding a pale-yellow glass before his eyes, the tint of the glass being so faint as hardly to disturb the natural colors of the objects; the use of a very pale-blue glass seemed, on the other hand, to darken up the landscape, as though a cloud were passing over the scene.

ELECTRIC SIGNALING ON ENGLISH RAILROADS.

By C. E. PASCOE.

I TAKE it for granted that most Americans who have traveled in England know of, if they don't actually know, Clapham Junction. It is a marvelous place is that Clapham Junction—a half-dozen or more naked-looking graveled platforms, destitute of almost every con-

venience in the shape of waiting and refreshment rooms, forming altogether one of the most important, not to say intricate, railway-depots in the United Kingdom. One arrives at a platform by a train belonging to one company going in one direction, and by turning right about, or walking three yards on the same platform, one may secure a seat in another train belonging to an entirely different company going no one knows whither. Once give way, or lose your head at this particular junction, and you may find yourself, should you happen to be wanting to go to the west of England, suddenly whirled away to the south, and *vice versa*. Even your traveling Londoner has an instinctive dread of "*the* Junction," as he familiarly terms it. Should you ever take up that indispensable requisite of English traveling, a Bradshaw, and stumble upon Clapham Junction in the list of stations your train is timed to stop at, go no farther. Don't tempt Fate. Rather court resignation. Throw yourself upon the cushions of your carriage, pitch Bradshaw out of the window, and in a moment of leisure work out this sum: If upon the average eight hundred trains (to say nothing of specials, excursions, and stray locomotives) pass through Clapham Junction in the course of twenty-four hours, allowing just about two minutes' interval of time between train A going out and train B coming in, what should be the chances of train B dashing into the tail of train A?

So remote as scarcely to be thought of, the reason being that the "block" system is in full force. What is this "block" system? To endeavor to answer that inquiry is the very object of this article.

To understand thoroughly what railway traveling in England really means, one should bear in mind a few facts now given for the purposes of this article, in the order of their importance.

At the beginning of last year there were in the United Kingdom about 15,500 miles of railway, distributed as follows: England and Wales, 11,000 miles; Scotland, 2,500 miles; Ireland, 2,000 miles; and 290 companies shared these miles of railroad between them. The total number of depots, or stations, as they are termed in England, including junctions and sidings, is about 10,000 for the whole kingdom; of these 6,000 are passenger-stations, giving approximately one station to about every two miles of railway, but not in reality, because there are no less than 150 stations in London and the suburbs alone. As a matter of course the great centre of the railway system of the United Kingdom is London. Every company which can by any possible means find a way to the capital does so, and strives to provide the route which will be most attractive to the public. To do this the majority of the companies must, of necessity, make use of the lines of the great companies having their termini in London. Only imagine the number of branch lines, junctions, and sidings, this must involve; what "shunting" of trains and adjusting of points there must be; what an efficient system of signaling must be required; what care,

steadiness, and application to work must be demanded of the men who look after the signals and points at the branch lines, junctions, and sidings. Take the Great Western line of England, for instance, with its 1,387 miles of road. Besides its own system, it falls in with the principal systems of the Bristol and Exeter, South Devon, North Wales, and ever so many more minor systems for the traffic of which it has in a measure, of course, to provide as well as for its own. Over all these lines trains are traveling daily at express speed, their ultimate destination being London. Now, express speed in England means an average rate of 47¾ miles an hour, a pace which is probably greater by ten miles than that attained on any other railroads in the world. Indeed, on the Great Western and Great Northern lines even this rate of traveling is exceeded. On the first-mentioned system a train runs 77¼ miles (from London to Swindon) without stopping, in 87 minutes, giving a uniform pace of 53¼ miles an hour: on the Great Northern a train completes the journey from London to Peterborough (76¼ miles) in 90 minutes. Just one little error on the part of the signal man, one omission to adjust the points on the part of his mate, and down swoops the express on to the wrong line, and the result is an appalling catastrophe such as happened at Wigan the other day.

In the above little sum, which I suggested to be worked out, I mentioned that about 800 trains passed through Clapham Junction regularly every day. You take your stand upon the platform. Whish-h-h—Bang—Rattle—a train has passed you. Take out your watch, mark the second-hand going round, and before it gets to 60—Whish-h-h—Bang—Plunge—a second train has rushed out into the open, to catch the first one up. But it can't. The line is blocked by the sharp-sighted man in the signal-box yonder, who has no fear even if a train per minute were to work through. He has nothing to do with time. His duties are to maintain a certain and invariable interval of space between two trains, and he does it. How does he do it? If the reader will be good enough to follow me into the signal-box, he shall see.

Not much of a place certainly. On the whole rather like a second-rate sea-shore shanty, stuck upon four posts, so placed it seems that every train going into the station, and every train coming out from it, shall rush full tilt against the box and smash it and its occupants to atoms. In reality, the signal-box is so situated to command for a certain distance a full view of one line just where it joins to another. Interiorly our box is not unlike an unfurnished private box at a theatre, into which some of the machinist's properties have been put by mistake. Regarding a printed notice on the wall that strangers are particularly requested not to distract the attention of the signal-man from his duties, we take a look round, and the general impression to be got from a cursory glance is that it must be rather jolly to be a signal-man. Every thing looks so clean and neat; there is plenty of excitement to be had in watching the trains from the win-

dow; the work does not appear to be very laborious, and what there is of it (which, truth to tell, is a great deal) would seem to be especially interesting and not unconnected with the gaining a full and accurate knowledge of the working of the electric telegraph. On the left-hand wall of the box as you enter, and on a level with the eye, are a number of little ebony handles, technically known as "keys," but variously termed in English railroad parlance "piston-keys" or "plungers." They are on the principle of the little "pea" bell fitted to the bedrooms of most large American hotels, and communicate telegraphically between the stations—"up" and "down." Over each of these "plungers" is an electric bell, which rings to give notice of the approach and departure of a train, its nature—that is, whether it is a passenger or goods, express or special—and to which company it belongs, when two or more companies have running powers over the same line. The custom universally adopted by English railroad companies to distinguish trains, and I believe it is the case with our own, too, in addition to the particular disks and lights carried upon the buffer-plank of the locomotive, is to blow the whistle a certain number of times when approaching a junction or station. The same system is adopted with the electric signals in the signal-box, only, in place of blowing the whistle, a bell is sounded. Every depression of the "plunger" transmits a current of electricity to the other station "up" or "down," as the case may be, which there sounds a bell or gong, and by varying the number of currents sent a code of signals is formed. For instance:

1	Depression of the "key"	Acknowledgment.
2	Depressions	Passenger-train.
3	"	Goods.
4	"	Special.
5	"	Obstruction-signal,

and so on. This code may, of course, be varied at pleasure; and it is possible to give fifteen distinct and unmistakable signals upon a bell by varying the number of beats and repetitions. By means of these bells, then, a perfect means of communication is kept up between two stations, signal-boxes, or gate-houses, on a railroad.

The fundamental principle of the "block" system which we are now endeavoring to explain is, that no train traveling in the same direction shall ever approach nearer to another than the distances which the signal-men's boxes are apart. These distances vary on English roads according to circumstances, but, so long as the signals are properly made by the signal-man, and attended to by the driver of the locomotive, it becomes simply impossible for one train to run into another. For sake of illustration, let us take three signal-boxes, which we shall call B, and C, and D, on a line of railroad between B and E. We will suppose that the express from a station A has arrived at B,

and is about to proceed on its journey to E, and that an ordinary train has preceded it a quarter of an hour, which would allow about time enough for it to "shunt" or go off into the siding at D. When the train has passed the signal-box at C, the signal-man there telegraphs to the one at B that the line is clear, which means that there is no train on the "up" line between stations B and C. Directly the express referred to arrives at B, the signal-man there, if he has received the signal "all clear," allows the train to pass him, and at once telegraphs to C that there is a train on the "up" line. The C signal-man, if he has received a signal from D of line clear, allows the express to pass him also, but, if not, he exhibits his signal accordingly. We will now suppose that the express is yet between B and C, and that another train, approaching in the same direction, whistles to the man at B for leave to go on. This is refused until the C signal-man telegraphs that the line is c ear. The same plan is carried out at every signal-box the train has to pass, of whatever nature it may be, whether "express," running at the rate of fifty-five miles an hour, or "goods," steaming along easily at a pace of twenty-five. It will thus be seen that, however great the traffic, it can be conducted with almost absolute safety, the only difference being that, with a very large number of trains per hour, the signal-boxes are placed nearer together, as on the Metropolitan or Underground Railroad of London, which has as near as possible one thousand trains passing over its system in the course of every twenty-four hours. No accident of any importance has ever occurred on this line.

But there are other objects in our signal-box besides plungers and little bells to attract attention. Four very noticeable toys—I use the term advisedly, for they struck me at once as being particularly suggestive of liliputian railroads, and dolls' houses, and toy signal-men—are the miniature electric semaphores used for instructing the signal-man as to setting the semaphore-signals on the line for the guidance of drivers of locomotives. Having stated the principle of the "block" system to be that no two following trains are to be allowed to proceed in the same direction upon the same section of line at the same time, it follows that a danger-signal must be exhibited and maintained at the station or depot from which a train has departed until it has been cleared out of the section of the line over which it is traveling. To do this effectually necessitates that this signal should be under the control of the signal-man toward whom the train is approaching; and no accident, mechanical or electrical, should be allowed to remove this signal until the train has arrived. The signals used on most of the English lines of railroad to guide the driver are, the raising and lowering of a semaphore arm to denote "danger" and "all clear." If it were possible to work these huge out-door signals by electricity, the system would be perfect; but, inasmuch as the power of electricity is circumscribed, the production of force sufficient

to actuate, with any degree of certainty, these exposed signals, has not yet been attained. It has become necessary, therefore, to rely upon small electrical instruments, miniatures of the out-door semaphores, which direct the signal-man in the box how to exhibit his out-door signals by displaying the signals which they themselves ought to give. The same principle which produces a blow upon the bell-signal lowers the semaphore arm on the miniature to "all clear." A current of electricity, flowing through the wire of an electro-magnet, converts the iron core into a magnet, and exerts precisely the same action upon a rocking lever that a pull or strain of a signal-wire does upon the large rocking lever of a signal-post. A counter-weight, when the current ceases, restores the arm to "danger," as it does in ordinary railroad-signals. So that the miniature semaphore will remain at "all clear" so long as a current flows, but, the moment the current ceases, the arm by the action of gravity flies up to "danger." It is impossible to lower the signal at one station except by the action of an electric current, and to maintain that signal at "all clear" except by the persistent effect of the battery at the other station. The signal, therefore, is under the sole control of the signal-man toward whom the train is approaching. The instrument employed to raise and lower this miniature signal is called a "switch," from the similarity of its appearance and construction to the switch-handles or levers employed to raise and lower the larger signals on the line. Its electrical construction is precisely similar to that of the "plunger." By removing the handle over from one side to the other, it places the battery in connection with the line wire, and thereby causes a current of electricity to flow which lowers the signal.

There were four of these miniature "switches" in our signal-box, and this was the way they appeared to us to work: When the switch-handle was placed so as to be nearest us, or On, no current was transmitted, and the little signal stood at "*danger ;*" when, however, it was pushed over farthest from us to Off, a current flowed, and the little arm was lowered to "all clear." As the arm could only be lowered when a current was flowing, it was only when the switch-handle was pushed over to Off that the "all-clear" signal could be given. Similarly, when the switch-handle was at On, the flow of electricity at once ceased, and the signal flew to "danger." The signal "all clear" could therefore only be given when the little switch was intentionally placed over to Off, and there was no other means of accomplishing this object by willfulness or accident. No accident, mechanical or electrical, could alter the miniature danger-signal. The man at our signal-box had the sole and complete control over the signal at the next box, and it was simply impossible for him to interfere with or alter the signal in his own box. This in effect is the "block" system, which answers so admirably on the principal lines of English railroad. The instructions given to signal-men who work the signals

we have been describing are as follows, and we give them that the reader, when next traveling upon an English line of railroad and passing a signal-box, may give a passing thought of thanks to the inventor of the "block" system, and the gentleman who framed these rules, Mr. William Henry Preece, of the Institute of Civil Engineers, and to the individual, let us hope, who follows them closely—the signal-man:

INSTRUCTIONS.

1. No train or engine is to be allowed to pass your box unless the electric signal for the section into which it is about to proceed stands at ALL CLEAR.

2. When a train has entered the section of line which you have protected (under Rule 4), you will signal to the next station, two beats on the bell *twice*, to signify "Train coming; be ready."

3. On the approach or arrival of the train or engine at your box, you will, provided the electric signal stands at ALL CLEAR, at once signal it on the bell to the next station in advance, thus:

If a passenger-train .. by 2 beats.
" goods-train..... " 3 "
" special or engine. " 4 "

4. This signal will be acknowledged by the corresponding station, by throwing his switch-handle over to "ON," thereby placing the electric signal at your station at DANGER, and protecting the line from any train following that already in the section.

5. You will acknowledge this signal by returning one beat of the bell.

6. On the arrival of the $\left\{\begin{matrix}\text{Down}\\\text{Up}\end{matrix}\right\}$ train at $\left\{\begin{matrix}\text{_____}\\\text{_____}\end{matrix}\right\}$, the signal-man at that station will pull his switch-handle over to OFF, thereby removing your danger-signal, intimating the arrival of the train and clearing the line.

7. This you will acknowledge by one beat on the bell.

8. In case any obstruction exists upon the line to necessitate its being blocked, give five sharp beats on the bell (which must be repeated), and raise the electric signal to *Danger*, which must be maintained as long as the obstruction lasts.

9. No signal is to be considered complete until it has been acknowledged.

I beg leave to state that this article is written without being at all acquainted with the system of signaling on American lines of railroad, so that I am unable to say how far our own bears comparison with the English system.

THE FACIAL ANGLE.

By RANSOM DEXTER, A. M., M. D.,
PROFESSOR OF ZOOLOGY AND PHYSIOLOGY IN THE UNIVERSITY OF CHICAGO.

THE methods of estimating the facial angle hitherto adopted by naturalists are all mere modifications of that proposed by Peter Camper, and consist in describing an angle with one line passing along the base of the skull, intersected by another which passes from the anterior portion of the upper jaw over the forehead.

Prof. Owen's definition is: "If a line be drawn from the occipital condyle along the floor of the nostrils, and be intersected by a second,

touching the most prominent parts of the forehead and upper jaw, the intersected angle is called the facial angle" (vol. ii., p. 572, "Anatomy of Vertebrates").

The relation of the face is not to the base of the skull, or the plane from the floor of the nostrils to its articulation to the backbone, but to the axis of the body; for the face, in the lowest class of animals that have a backbone, the fish, is in line with the base of the skull, the axis of the body, and the dorsal surface of the animal; and in man, the highest class, the face is in line with the abdominal surface, and axis of the body. But the base of the skull does not keep in harmony, but varies irregularly. Then, there are numerous *other* elements than the bones at the base of the skull, that are factors in the aspect of the face, as, the modified development of other bones of the skull, peculiar development of bones of the face, and relation of the bones of the face that are *not* attached to the *skull*, but to other *facial bones*.

To make the subject more clearly comprehensible, it will be necessary to trace more in detail the development of the division of animals to be considered.

The subject of the facial angle has occupied the attention of philosophers from the earliest antiquity. Their theories, though vague, unsatisfactory, and uninteresting in themselves, yet tend conclusively to show that some patent general principle underlies the whole domain of the subject. Confined, as they were, to the narrow limits of the varieties of the human race, they would get only a part of the evidence that is so beautifully illustrated, when we include the whole sub-kingdom of animals to which we belong.

At the beginning of the present century, Cuvier, Von Baer, and others, discovered and established the great laws of evolution. The laws thus elucidated were: 1. That the entire animal kingdom originates from an ancestral egg; eggs, too, though differing in physical appearance, that are quite similar in structure. 2. That every animal, in its evolution, had to pass through the several stages of ovulation, fertilization, germination, and development, before it could maintain an independent existence. 3. That in their development they assumed but few primary structural patterns or types.

After the promulgation of the above doctrines, a series of investigations ensued, which brought naturalists to approximate a general agreement that there are only five general morphological or form-types of animals. Every animal, then, of the entire animal kingdom, must be classed in one or the other of these five sub-kingdoms, and each division thus classed has one fundamental plan of structure. The only way in which the animals of each sub-kingdom can differ is in the manner of executing their physiological functions.

In considering, then, any of the great physiological and philosophical questions that are based upon a uniformity of primitive type-development, we find that many useful lessons may be learned by including

in our considerations every class of animals in which the specialization to be considered appears. For example, every animal belonging to the vertebrate sub-kingdom of animals agrees with every other animal of the same sub-kingdom in the following distinctive characteristics—characteristics, too, that we shall find involved in our considerations of the subject of the facial angle: In all, the head and vertebral column are composed of a number of definite segments, arranged along a longi-

FIG. 1.

tudinal axis; each segment of this framework is normally composed of a body and two diverging, ring-like formations; the dorsal containing the brain and spinal cord, the ventral, or abdominal, containing the organs of nutrition, as the alimentary canal, circulating and eliminating organs. Every vertebrate animal, then, is possessed of two tubes of framework: the one, to protect the brain and spinal cord; the other, the organs of nutrition. These tubes are subject to very great variation, and are modified, as by a master's hand, to meet the necessities that their various specializations of function may demand. The great modification in the calibre of the dorsal tube in different classes of the vertebrates, as well as the great variation in shape of the elements which compose that arch, is apparent to every one. In the region of the spine, the elements that compose the segments of the arch are rounded, and at some distance apart, while in the *cranial* (skull) region they are flattened, spread out, so as to unite and form sutures, thus making a solid brain-case, for the protection of the softer and more massive nerve-matter.

The elements composing the nutritive case are the jaws, ribs, and pelvic girdle. These, like the spinal elements, are subject to great modification, owing to the immense range of variation to which their specializations are subjected. The difference in the facial develop-

FIG. 2.

FIG. 3.

ments can well be imagined by calling to mind the various countenances of animals, from the fish to man. The angle of the face is simply and properly, I think, indicated by the relation expressed by two lines: the first, or base line, corresponding to the axis of the body; the other, diverging, or face line, drawn from the anterior margin of the upper jaw, over the centre of the forehead. The relation and angles formed by these two lines, and their intersections thus indicated, express the relation and comparative development at the union of the two primitive tubes, the *neural*, or skull, and *hemal* (face), at the anterior extremity or head of a vertebrate animal.

As before stated, authors have hitherto established the base-line from the floor of the nostrils, to the articulation of the occipital bone to the vertebræ. This is a grave error, and one, no doubt, that has contributed its share to depreciate the subject as an index to the mental caste of a vertebrate animal. For, by adopting this method, we are subject to the enormous error of ninety degrees in passing through the sub-kingdom, all of which we lose, little by little, as we ascend the scale of animals of this type, or form of structure. And yet they make this application through the entire vertebrate series. Yet, by referring to the cut, we find the face of the lowest class of the type, the fish, to be in direct line with the dorsal surface of the animal, and hence the base and diverging lines are parallel; while, in the highest of the type, that of man, the face is in line with the ventral or abdominal surface. Again, after effecting a grand variation of one hundred and eighty degrees, or the half of a circle, the two lines are once more parallel.

What, then, are the factors in the phenomena of the great change of the aspect of the face, with such a modification of its constituents, from a line of the dorsal to that of the abdominal surface, all of which is effected by almost imperceptible gradations, as we ascend the series from the fish to man? It is by the modification of the anterior extremities of these cranio-vertebral canals in the development and increase of the cerebral hemispheres, which is that part of the brain that is recognized as the seat of thought, and their influence upon other

structures, that the whole change is wrought from a complete dominant power of the physical over the mental, to the reverse, viz., an entire dominant ascension, in some instances, of the *moral* and *intellectual* over the physical. *In every vertebrate animal, then, there are two factors, the physical and mental; the facial angle is the typical expression or exponent of the relative strength or condition of each.*

It may be observed that, with the ascension of these animals, the relative size of the brain-case, or skull, increases with a proportionate diminution of the bones of the face, and of the projection of the jaws in front of the orbits.

In the cold-blooded fish, the serpent, and the crocodile, the cavity for the brain is small, but little more than a prolongation of the canal for the spinal cord, with a disproportionate development of the organs of mastication, thus enabling them to execute the strongest instinct of the lower animals, namely, to slay and devour. In the bird class, the brain is somewhat larger, but is contained in the posterior part of the cranium, they manifesting but a slight mental superiority over the reptile. In the dog, over whom man is lord, and the noble horse, the brain is much larger; the facial line intersects at about a right angle with the base line, or vertebral axis. In these animals we begin to discover the rudiments of some of those more noble motives which are so abundantly lavished upon *some* of the higher animals.

The monkey and the anthropoid, or man-like apes, express in a very characteristic manner many of the mental attributes of the lower varieties of the human species. Nor is this to be wondered at, when we consider the close anatomical relation which subsists between the two, and the enormous development of the cerebral hemispheres as compared with the lower classes of the same type.

The profile of the idiot is the next introduced in the cut, to illustrate the influence upon the size and shape of the *cranium*, or skull, that an arrest of brain-development has wrought, and which corresponds to the mental manifestations of its subject.

The other three profile views represent the savage, the half-civilized, and the *cultivated* races of man. The first of the three, the one next to the view of the idiot, is a drawing from a correct engraving of the celebrated North American Indian chief Black Hawk, and corresponds in brain capacity, facial angle, and mental powers, very nearly to the other savage races, viz., the Malayan and Ethiopian. The next that is represented in the cut is the half-civilized Mongolian race, illustrating very nicely the ratio of the two factors, physical and mental. The last is a representation of the highly-cultivated Caucasian race, and is a correct profile view of one of the most illustrious statesmen that this or any other nation ever possessed—that of Daniel Webster.

In the lowest of the type, the fish, we find the brain least developed, and the cerebral hemispheres, or instrument of thought, bearing

the smallest proportion, either to its own concomitant structures, or to the rest of the body. The actual weight of a common codfish was 14,875 grains; the brain weighed only 9½ grains; thus making the ratio of 1 to 1,565. In man, the average weight of the brain is about 3 pounds, the medium weight of the body 150 pounds, making a ratio of 1 to 50. The above is a correct statement of the relative weight of the brain to the body of the lowest of the type, the fish, and the highest, man; showing the ratio of the weight of the brain in man, to that of the body, to be over 31 times greater than the same ratio in the fish. But, if we estimate the proportionate weight of merely the *cerebral hemispheres*, or the instruments of thought, to that of the body in the fish and man, we obtain a difference of 124, which expresses the number of times the cerebral hemispheres of man are greater than those of the fish; in other words, if the body of a fish and that of man were of equal weight, the cerebral hemispheres of the latter would weigh 124 times more than those of the former. Further, the relative weight of the cerebral hemispheres, as we ascend from the fish through the vertebrate sub-kingdom of animals, will be found to correspond to the variation of the face-line from a parallel with the dorsal surface.

To recapitulate: 1. The size and weight of the brain will be found to increase with the angle of the face to the axis of the body. 2. The expansion of the brain-case, with a proportionate diminution of the facial bones, is an invariable accompaniment of an increased facial angle throughout the vertebrate sub-kingdom of animals. 3. The mental manifestation and power have a direct relation to the angle above indicated. 4. The position assumed by the body of the animal in its change from the horizontal to the perpendicular attitude, also very generally agrees with the facial angle of its subject. 5. The projection of the jaws, in front of the ocular orbits, is also a correlative index to the above data. 6. The relative ascendency of the two factors, the physical and mental, with their numerous phenomena, is an index to all of the above relations, and shows very conclusively the gradual turning from the lowest instincts of the brute to the most complex mental powers of man.

DISPOSAL OF THE DEAD.

By SIR HENRY THOMPSON,
PROFESSOR OF CLINICAL SURGERY IN UNIVERSITY COLLEGE, LONDON.

AFTER Death! The last faint breath had been noted, and another watched for so long, but in vain. The body lies there, pale and motionless, except only that the jaw sinks slowly but perceptibly. The pallor visibly increases, becomes more leaden in hue,

and the profound, tranquil sleep of Death reigns where just now were life and movement. Here, then, begins the eternal rest.

Rest! no, not for an instant. Never was there greater activity than at this moment exists in that still corpse. Activity, but of a different kind to that which was before. Already a thousand changes have commenced. Forces innumerable have attacked the dead. The rapidity of the vulture, with its keen scent for animal decay, is nothing to that of Nature's ceaseless agents now at full work before us. That marvelously complex machine, but this moment the theatre of phenomena too subtile and too recondite to be comprehended; denotable only by phraseology which stands for the unknown and incomputable—vital, because more than physical, more than chemical—is now consigned to the action of physical and chemical agencies alone. And these all operating in a direction the reverse of that which they held before death. A synthesis, then, developing the animal being. The stages of that synthesis, now, retraced, with another end, still formative, in view. Stages of decomposition, of decay, with its attendant putrescence; process abhorrent to the living, who therefore desire its removal. "Bury the dead out of my sight," is the wholly natural sentiment of the survivor.

But Nature does nothing without ample meaning; nothing without an object desirable in the interest of the body politic. It may, then, be useful to inquire what must of necessity happen if, instead of burying or attempting to preserve the dead, Nature follows an unimpeded course, and the lifeless animal is left to the action of laws in such case provided.

It is necessary first to state more exactly the conditions supposed to exist. Thus, the body must be exposed to air; and must not be consumed as prey by some living animal. If it is closely covered with earth or left in water, the same result is attained as in the condition first named, although the steps of the process may be dissimilar.

The problem which Nature sets herself to work in disposing of dead animal matter is always one and the same. The order of the universe requires its performance; no other end is possible. The problem may be slowly worked, or quickly worked; the end is always one.

It may be thus stated: The animal must be resolved into—

a. Carbonic acid (CO_2), water (HO), and ammonia (NH_3).

b. Mineral constituents, more or less oxidized, elements of the earth's structure: lime, phosphorus, iron, sulphur, magnesia, etc.

The first group, gaseous in form, go into the atmosphere.

The second group, ponderous and solid, remain where the body lies, until dissolved and washed into the earth by rain.

Nature's object remains still unstated: the constant result of her work is before us; but wherefore are these changes? In her wonderful economy she must form and bountifully nourish her vegetable

progeny; twin-brother life, to her, with that of animals. The perfect balance between plant existences and animal existences must always be maintained, while "matter" courses through the eternal circle, becoming each in turn.

To state this more intelligibly by illustration: If an animal be resolved into its ultimate constituents in a period according to the surrounding circumstances, say, of four hours, of four months, of four years, or even of four thousand years—for it is impossible to deny that there may be instances of all these periods during which the process has continued—those elements which assume the gaseous form mingle at once with the atmosphere, and are taken up from it without delay by the ever-open mouths of vegetable life. By a thousand pores in every leaf the carbonic acid which renders the atmosphere unfit for animal life is absorbed, the carbon being separated and assimilated to form the vegetable fibre, which, as wood, makes and furnishes our houses and ships, is burned for our warmth, or is stored up under pressure for coal. All this carbon has played its part, "and many parts," in its time, as animal existences from monad up to man. Our mahogany of to-day has been many negroes in its turn, and before the African existed was integral portions of many a generation of extinct species. And, when the table, which has borne so well some twenty thousand dinners, shall be broken up from pure debility and consigned to the fire, thence it will issue into the atmosphere once more as carbonic acid, again to be devoured by the nearest troop of hungry vegetables—green peas or cabbages in a London market-garden, say—to be daintily served on the table which now stands in that other table's place, and where they will speedily go to the making of "lords of the creation." And so on, again and again, as long as the world lasts.

Thus it is that an even balance is kept—demonstrable to the very last grain if we could only collect the data — between the total amounts of animal and of vegetable life existing together at any instant on our globe. There *must* be an unvarying relation between the decay of animal life and the food produced by that process for the elder twin, the vegetable world. Vegetables first, consumed by animals either directly or indirectly, as when they eat the flesh of animals who live on vegetables. Secondly, these animals daily casting off effete matters, and by decay after death providing the staple food for vegetation of every description. One the necessary complement of the other. The atmosphere, polluted by every animal whose breath is poison to every other animal, being every instant purified by plants, which, taking out the deadly carbonic acid and assimilating carbon, restore to the air its oxygen, first necessary of animal existence.

I suppose that these facts are known to most readers, but I require a clear statement of them here as preliminary to my next subject; and in any case it can do no harm to reproduce a brief history of this mar-

velous and beautiful example of intimate relation between the two kingdoms.

I return to consider man's interference with the process in question just hinted at in the quotation, "Bury the dead out of my sight."

The process of decomposition affecting an animal body is one that has a disagreeable, injurious, often fatal influence on the living man if sufficiently exposed to it. Thousands of human lives have been cut short by the poison of slowly-decaying and often diseased animal matter. Even the putrefaction of some of the most insignificant animals has sufficed to destroy the noblest. To give an illustration which comes nearly home to some of us—the graveyard pollution of air and water alone has probably found a victim in some social circle known to more than one who may chance to read this paper. And I need hardly add that in times of pestilence its continuance has been often due mainly to the poisonous influence of the buried victims.

Man, then, throughout all historic periods, has got rid of his dead kin after some fashion. He has either hidden the body in a cave and closed the opening to protect its tenant from wild beasts, for the instinct of affection follows most naturally even the sadly-changed remains of our dearest relative; or, the same instinct has led him to embalm and preserve as much as may be so preservable — a delay only of Nature's certain work — or the body is buried beneath the earth's surface, in soil, in wood, in stone, or metal—each mode another contrivance to delay, but never to prevent, the inevitable change. Or, the body is burned, and so restored at once to its original elements, in which case Nature's work is hastened, her design anticipated, that is all. And, after burning, the ashes may be wholly or in part preserved in some receptacle in obedience to the instinct of the survivor, referred to above. All forms of sepulture come more or less under one of these heads.[1]

One of the many social questions waiting to be solved, and which must be solved at no very remote period, is, Which of these various forms of treatment of the dead is the best for survivors?

This question may be regarded from two points of view, both possessing importance, not equally perhaps; but neither can be ignored.

A. From the point of view of Utility; as to what is best for the entire community.

B. From the point of view of Sentiment; the sentiment of affectionate memory for the deceased, which is cherished by the survivor.

I assume that there is no point of view to be regarded as belonging to the deceased person, and that no one believes that the dead has any interest in the matter. We who live may anxiously hope—as I should hope at least—to do no evil to survivors after death, whatever

[1] "Burial at sea" is a form of exposure, the body being rapidly devoured by marine animals.

we may have done of harm to others during life. But, being deceased, I take it we can have no wishes or feelings touching this subject. What is best to be done with the dead is then mainly a question for the living, and to them it is one of extreme importance. When the globe was thinly-peopled, and when there were no large bodies of men living in close neighborhood, the subject was an inconsiderable one and could afford to wait, and might indeed be left for its solution to sentiment of any kind. But the rapid increase of population forces it into notice, and especially man's tendency to live in crowded cities. There is no necessity to prove, as the fact is too patent, that our present mode of treating the dead, namely, that by burial beneath the soil, is full of danger to the living. Hence intramural interment has been recently forbidden, first step in a series of reforms which must follow. At present we who dwell in towns are able to escape much evil by selecting a portion of ground distant—in this year of grace 1873—some five or ten miles from any very populous neighborhood, and by sending our dead to be buried there—laying by poison nevertheless, it is certain, for our children's children, who will find our remains polluting their water-sources, when that now distant plot is covered, as it will be, more or less closely by human dwellings. For it can be a question of time only when every now waste spot will be utilized for food-production or for shelter, and when some other mode of disposing of the dead than that of burial must be adopted. If, therefore, burial in the soil be certainly injurious either now or in the future, has not the time already come to discuss the possibility of replacing it by a better process? We cannot too soon cease to do evil and learn to do well. Is it not indeed a social sin of no small magnitude to sow the seeds of disease and death broadcast, caring only to be certain that they cannot do much harm to our own generation? It may be granted, to anticipate objection, that it is quite possible that the bodies now buried may have lost most, if not all, their power of doing mischief by the time that the particular soil they inhabit is turned up again to the sun's rays, although this is by no means certain; but it is beyond dispute that the margin of safety as to time grows narrower year by year, and that pollution of wells and streams which supply the living must ere long arise wherever we bury our dead in this country. Well, then, since every buried dead body enters sooner or later into the vegetable kingdom, why should we permit it, as it does in many cases, to cause an infinity of mischief during the long process?

Let us at this point glance at the economic view of the subject, for it is not so unimportant as, unconsidered, it may appear. For it is an economic subject whether we will it or not. No doubt a sentiment repugnant to any such view must arise in many minds, a sentiment altogether to be held in respect and sympathy. Be it so; the question remains strictly a question of prime necessity in the economic

system of a crowded country. Nature will have it so, whether we like it or not. She destines the material elements of my body to enter the vegetable world on purpose to supply another animal organism which takes my place. She wants me, and I *must* go. There is no help for it. When shall I follow—with quick obedience, or unwillingly, truant-like, traitor-like, to her and her grand design? Her capital is intended to bear good interest and to yield quick return; all her ways prove it—"increase and multiply" is her first and constant law. Shall her riches be hid in earth to corrupt and bear no present fruit, or be utilized, without loss of time, value, and interest, for the benefit of starving survivors? Nature hides no talent in a napkin; we, her unprofitable servants only, thwart her ways and delay the consummation of her will.

Is a practical illustration required? Nothing is easier. London was computed, by the census of 1871, to contain 3,254,260 persons, of whom 80,430 died within the year. I have come to the conclusion, after a very carefully-made estimate, that the amount of ashes and bone-earth—such as is derived by perfect combustion—belonging to and buried with those persons, is by weight about 206,820 pounds. The pecuniary value of this highly-concentrated form of animal solids is very considerable. For this bone-earth may be regarded as equivalent to at least six or seven times its weight of dried but unburned bones, as they ordinarily exist in commerce. The amount of other solid matters resolvable by burning into the gaseous food of plants, but rendered unavailable by burial for, say fifty or a hundred years or more, is about 5,584,000 pounds, the value of which is quite incalculable, but it is certainly enormous as compared with the preceding.

This is for the population of the metropolis only; that of the United Kingdom for the same year amounted to 31,483,700 persons, or nearly ten times the population of London. Taking into consideration a somewhat lower death-rate for the imperial average, it will at all events be quite within the limit of truthful statement to multiply the above quantities by nine in order to obtain the amount of valuable economic material annually diverted in the United Kingdom, for a long term of years, from its ultimate destiny by our present method of interment.

The necessary complement of this ceaseless waste of commodity most precious to organic life, and which must be replaced, or the population could not exist, is the purchase by this country of that same material from other countries less populous than our own, and which can, therefore, at present spare it. This we do to the amount of much more than half a million pounds sterling per annum.[1]

Few persons, I believe, have any notion that these importations

[1] Value of bones imported into the United Kingdom, of which by far the larger part is employed for manure, has been in 1866, £409,590; 1869, £600,029; 1872, £753,185. —*Statistical Abstract*, No. 20.—Spottiswoode, 1873.

of foreign bones are rendered absolutely necessary by the hoarding of our own some six feet below the surface. The former we acquire at a large cost for the original purchase and for freight. The latter we place, not in the upper soil where they would be utilized, but in the lower soil, where they are not merely useless, but where they often mingle with and pollute the streams which furnish our tables. And, in order to effect this absurd, if not wicked result, we incur a lavish expenditure! I refer, of course, to the enormous sums which are wasted in effecting burial according to our present custom, a part of the question which can by no means be passed over. For the funeral rites of the 80,000 in London last year, let a mean cost of ten pounds per head be accepted as an estimate which certainly does not err on the side of excess.[1] Eight hundred thousand pounds must therefore be added as absolute loss, to the costs already incurred in the maintenance of the system. Thus we pay every way and doubly for our folly.

What, then, is it proposed to substitute for this custom of burial? The answer is easy and simple. Do that which is done in all good work of every kind—follow Nature's indication, and do the work she does, but do it better and more rapidly. For example, in the human body she sometimes throws off a diseased portion in order to save life, by slow and clumsy efforts, it is true, and productive of much suffering; the surgeon performs the same task more rapidly and better, follows her lead, and improves on it. Nature's many agents, laden with power, the overaction of which is harmful, we cannot stop, but we tame, guide, and make them our most profitable servants. So here, also, let us follow her. The naturally slow and disagreeable process of decomposition which we have made by one mode of treatment infinitely more slow and not less repulsive, we can, by another mode of treatment, greatly shorten, and accomplish without offense to the living. What in this particular matter is naturally the work of weeks or months, can be perfectly done in an hour or two.

The problem to be worked is: Given a dead body, to resolve it into carbonic acid, water, and ammonia, and the mineral elements, rapidly, safely, and not unpleasantly.

The answer may be practically supplied in a properly-constructed furnace. The gases can be driven off without offensive odor—the

[1] Items comprised in the calculation:

1. Cost of shroud, coffin, labor of digging a grave—essential now in all burials.
2. Cost of funeral-carriages, horses, trappings, and accoutrements.

Ornamental coffins in wood and metal.

Vaults and monumental art—more or less employed in all funerals above the rank of pauper.

The cost of simple modes of transit is not included in the calculation, because necessary in any case, whatever the destination of the body. The above-named items are only necessary in the case of interment in a grave; and not one would be required, for example, in the case of cremation, or burning of the body.

mineral constituents will remain in a crucible. The gases will, ere night, be consumed by plants and trees. The ashes or any portion of them may be preserved in a funeral-urn, or may be scattered on the fields, which latter is their righteous destination. No scents or balsams are needed, as on Greek and Roman piles, to overcome the noxious effluvia of a corpse burned in open air. Modern science is equal to the task of thus removing the dead of a great city without instituting any form of nuisance; none such as those we tolerate everywhere from many factories, both to air and streams. Plans for the accomplishment of this have been considered; but discussion of the subject alone is aimed at here. To treat our dead after this fashion would return millions of capital without delay to the bosom of Mother Earth, who would give us back large returns at compound interest for the deposit.

Who can doubt now that the question is one of vital economy to the people of this country? This is still no reason why it should not be considered from the point of view of sentiment. And what has sentiment to urge on behalf of the present process? Let us see what the process is.

So far as I dare! for, could I paint, in its true colors, the ghastly picture of that which happens to the mortal remains of the dearest we have lost, the page would be too deeply stained for publication. I forbear, therefore, to trace the steps of the process which begins so soon and so painfully to manifest itself after that brief hour has passed, when "she lay beautiful in death." Such loveliness as that, I agree, it might be treason to destroy, could its existence be perpetuated, and did not Nature so ruthlessly and so rapidly blight her own handywork, in furtherance of her own grand purpose. The sentiment of the survivor on behalf of preserving the beauty of form and expression, were it possible to do so, would, I confess, go far to neutralize the argument based on utility, powerful as it is. But a glimpse of the reality which we achieve by burial would annihilate, in an instant, every sentiment for continuing that process. Nay, more, it would arouse a powerful repugnance to the horrible notion that we too must some day become so vile and offensive, and, it may be, so dangerous; a repugnance surmountable only through the firm belief that after death the condition of the body is a matter of utter indifference to its dead lifetenant. Surely if we, the living, are to have sentiments, or to exercise any choice about the condition of our bodies after death, those sentiments and that choice must be in favor of a physical condition which cannot be thought of either as repulsive in itself or as injurious to others.

There is a source of very painful dread, as I have reason to know, little talked of, it is true, but keenly felt by many persons, at some time or another, the horror of which to some is inexpressible. It is the dread of premature burial; the fear lest some deep trance should be mistaken for death, and that the awakening should take place too

late. Happily, such occurrences must be exceedingly rare, especially in this country, where the interval between death and burial is considerable, and the fear is almost a groundless one. Still, the conviction that such a fate is possible, which cannot be altogether denied, will always be a source of severe trial to some. With cremation, no such catastrophe could ever occur; and the completeness of a properly conducted process would render death instantaneous and painless, if by an unhappy chance any individual so circumstanced were submitted to it. But the guarantee against this danger would be doubled, since inspection of the entire body must of necessity immediately precede the act of cremation, no such inspection being possible under the present system.

In order to meet a possible objection to the substitution of cremation for burial, let me observe that the former is equally susceptible with the latter of association with religious funereal rites, if not more so. Never could the solemn and touching words, "ashes to ashes, dust to dust," be more appropriately uttered than over a body about to be consigned to the furnace; while, with a view to metaphor, the dissipation of almost the whole body in the atmosphere, in the ethereal form of gaseous matter, is far more suggestive as a type of another and a brighter life, than the consignment of the body to the abhorred prison of the tomb.

I do not propose to describe here the processes which have been employed, or any improved system which might be adopted for the purpose of insuring rapid and perfect combustion of the body, although much might be said in reference to these matters. There is no doubt that further experiments and research are wanting for the practical improvement of the process, especially if required to be conducted on a large scale. Something has been already accomplished, and with excellent results. I refer to recent examples of the process as practised by Dr. L. Brunetti, Professor of Pathological Anatomy in the University of Padua. These were exhibited at the Exposition of Vienna, where I had the opportunity of examining them with care. Prof. Brunetti exposed the residue from bodies and parts of bodies on which he had practised cremation by different methods, and the results of his latest experience may be summarized as follows: The whole process of incineration of a human adult body occupied three and a half hours. The ashes and bone-earth weighed 1.70 kilometre, about three pounds and three-quarters avoirdupois. They were of a delicate white, and were contained in a glass box about twelve inches long, by eight inches wide, and eight deep. The quantity of wood used to effect absolute and complete incineration may be estimated from its weight, about 150 pounds. He adds that "its cost was one florin and twenty kreuzers," about two shillings and fourpence English. The box was that marked No. IX. in the case, which was No. 4,149 in the catalogue: Italian.

In an adjacent case was an example of mummification, by the latest and most successful method. By a series of chemical processes it has been attempted to preserve in the corpse the appearance natural to life, as regards color and form. Admirable as the result appears to be, in preserving anatomical and pathological specimens of the body, it is, in my opinion, very far from successful when applied to the face and hand. At best, a condition is produced which resembles a badly-colored and not well-formed waxen image. And the consciousness that this imperfect achievement is the real person and not a likeness, so far from being calculated to enhance its value to the survivor, produces the very painful impression, as it were, of a debased original; while, moreover, it is impossible not to be aware that the substitution of such an image for the reality must in time replace the mental picture which exists, of the once living face lighted by emotion and intelligence, of which the preserved face is wholly destitute.

To return to the process of cremation. There are still numerous considerations in its favor which might be adduced, of which I shall mention only one; namely, the opportunity it offers of escape from the ghastly but costly ceremonial which mostly awaits our remains after death. How often have the slender shares of the widow and orphan been diminished in order to testify, and so unnecessarily, their loving memory of the deceased, by display of plumes and silken scarfs about the unconscious clay! And, again, how prolific of mischief to the living is the attendance at the burial-ground, with uncovered head, and damp-struck feet, in pitiless weather, at that chilling rite of sepulture! Not a few deaths have been clearly traceable to the act of offering that "last tribute of respect."

Perhaps no great change can be expected at present in the public opinions current, or rather in the conventional views which obtain, on the subject of burial, so ancient is the practice, and so closely associated is it with sentiments of affection and reverence for the deceased. To many persons, any kind of change in our treatment of the dead will be suggestive of sacrilegious interference, however remote, either in fact or by resemblance to it, such change may be. Millions still cherish deep emotions, connected both with the past and the future, in relation to the "Campo Santo," and the annual "Jour des Morts." And many of these might be slow to learn that, if the preservation of concrete remains, and the ability to offer the tribute of devotion at a shrine be desired, cremation equally, if not better than burial, secures those ends. On the other hand, I know how many there are, both in this country and abroad, who only require the assurance that cremation is practically attainable to declare their strong preference for it, and to substitute it for what they conceive to be the present defective and repulsive procedure. A few such might, by combination for the purpose, easily examine the subject still further by experiment, and would ultimately secure the power, if they desired, to put it in practice for

themselves. And the consideration of the subject which such examples would afford, could not fail to hasten the adoption of what I am fairly entitled to call, the Natural, in place of the present Artificial Treatment of the body after death.—*Contemporary Review.*

THE FUTURE OF ALCHEMY.

By CHARLES FROEBEL.

THERE are few ideas more fatal to the exercise of that prophetic sight, by which we hope to penetrate the uncertainty of the what-is-to be, and distinguish the dark forms of the future, than the two notions: that history repeats itself, and that any form of feeling, of thought, or of motive, when once extinguished, must forever remain so. Though widely accepted, these two notions evidently contradict each other, and this contradiction is in itself a sufficient proof of their necessary mutual limitation. Yet, when limited by comparison, the two ideas find a joint expression in the moral law, that while infallibility is not of the human mind, and while all our views and forms of mental activity enshrine but a spirit of verity in a clay of illusion, it is only this body of error which the scythe of Time consigns to the grave, while the immortal soul of truth lives on.

Some centuries ago, the system of ideas known to history as Alchemy held universal sway over the minds of men; now there are none, among the cultivated at least, who dare to defend its assertions. And yet we may inquire what there was in these ideas that so commended them to men's minds, that at a time their authority was almost beyond dispute. What, we may ask, was the soul of truth, the immortal part, in the day-dreams of wealth, of power and of beauty, of magic and mystery, which formed the erroneous body of alchemistic belief?

The opinion most widely and popularly entertained at the present time ascribes to the alchemistical pursuits of the middle ages a mixed character: it holds the aim of alchemy to have mainly consisted in the transmutation of the baser metals into gold; it regards the alchemist as a man who, intensely selfish in his purpose, bore either the character of the unreasoning, visionary dreamer, of the magician moving among the phantoms of superstition, or of the charlatan and cheat living upon the credulity of the avaricious, and who sought, in the application of an exceedingly limited stock of scientific knowledge, the means for the accomplishment of his ends.

But, to the thoughtful student of history—not the history of political events, it is true, nor the history of science, or of any other isolated and abstract phase of human activity, but of history in its highest conception; a history which seeks and finds, in each of the

phases of life, the determining influences of all the others—the face of alchemy wears a different aspect.

At the time when alchemistic views were most widely disseminated and accepted, and alchemistic pursuits most widely, frequently followed, alchemy had one chief central object—the production of the philosopher's stone, a substance of marvelous properties and power. By those who claimed to possess it, it was generally described as a red, glass-like powder. When it was projected, that is to say, inclosed in wax, and thrown upon any base metal in a state of fusion, it instantly ennobled it, converting it into gold. When it was taken as a medicine, it was not only productive of perfect health, but even effaced the effects of time, bestowing all but eternal youth. And, even more than this, it was held to purge its fortunate possessor of all sin and moral evil. The transcendent value of such a substance is readily understood, and it is not to be wondered at that philosophical voyages, undertaken in its search, formed at a time the favorite enterprise of the alchemistic adventurer. But these attempts at its preparation were fraught with innumerable difficulties, beset by untold obstacles. The philosopher's stone was not held to be obtainable from any and every substance, but only from the peculiar material known in those days as primeval matter. Where this material was to be found no one could clearly state; the alchemists refer to its origin in dark, mysterious, unintelligible language. Hence it was sought far and near; in all countries; in the mineral, the vegetal, and the animal world; in the earth, the air, and the waters. According to the statement of the alchemist, he converted this peculiar material into another—the philosophical mercury or pure spirit of metallicity. Joining this with philosophical gold—that is to say, the pure spirit of goldenness—he placed the strange mixture in a certain vessel, the philosopher's egg, heated it in the philosopher's furnace, and hatched the philosopher's stone. It is scarcely necessary to say that the substances named do not exist. The process of making the stone was expressed in dark, enigmatical language. The open communication of the secret was held to be sinful, and liable to be punished by the instantaneous annihilation of the offender. These were the means and purposes of alchemy in the most exalted stage of its development, which it had attained toward the middle of the fourteenth century. Before the thirteenth it was immature; after the fifteenth it fell into decay.

The current of alchemistic opinions and pursuits issued from the dark ground of the Egyptian temple. Gathering the influences of Oriental Christianity, and taking in those of the Mohammedan torrent, it flowed away to the bleak shores of culture in the Christianized North. Egypt endowed it with its veil of mystery and its sacred character. The philosophy of antiquity bestowed upon it its fatal birth-gift of theoretical error. In Egypt it had been combined with astronomy and astrology, and, when that country passed under the sway of the Moham-

medan conquerors, the alliance of these pursuits was further strengthened by the fatalism of the Arabian. Seeking for the philosopher's stone an ideal of material perfection, and uniting with this pursuit that of the physician, the alchemist was led to regard the imperfection of the baser metals as a disease, the supposed operation of the stone as a process of healing, and to ascribe to it the properties of a universal medicine. Transferred to northern soil, at the time when mediæval Christianity attained its most exalted development, alchemy became thoroughly infused with the religious spirit of the period and its tendency to regard things material as analogous to and symbolical of things spiritual. Passing into the shadow of the cloud and mist-born Northern deities, still hovering over the thrones from which they had been hurled by the Christian angelic host, alchemistic pursuits became involved with the belief in magic and witchcraft. And then the great spiritual revolution which struck at the power of Catholic Rome also weakening the authority of ancient alchemistic views, they became the adroitly-wielded weapons of swindler and charlatan, who were only disarmed when the calm criticism of chemical science disproved the assertions of fraud.

But, at the time when the belief in the reality of the philosopher's stone was general among the cultivated as well as the ignorant, alchemistic hypocrisy was not common. More frequently, then, the alchemist was either an excited enthusiast, led astray by the mirage of his hope, or the cautious commentator who lent the weight of his name merely to give currency to the reports of older authorities. Nor was covetousness always the leading motive of the alchemists. Some of the most illustrious of them apparently persevered in their search for the philosopher's stone without a single sordid thought; many sought to make their pursuit tributary to the healing art; many also regarded their labor as one of the duties of a life of religious devotion.

Alchemy is often represented as immature chemical science, but even this view is only partially correct. The essence of science consists in experimental investigation; but, though many of the alchemists made discoveries, and some of them were investigators, the greater number, and some of the most illustrious, were rather men who, born to the habit of religious enthusiasm, and led by a beacon-light from the ideal world across the threshold of reality, only now and then stumbled over a new fact. Closer by far is the relationship subsisting between the alchemy of the past and the chemical technics of to-day. Most generally, the aim of the alchemist was not to discover, but to create. Indeed, alchemy had a constant purpose—the production of a perfect agent of chemical change—the philosopher's stone. It was a purpose which was never accomplished, an aim which could not possibly be attained—at least, not in the way and time dreamt of by the alchemistic enthusiast, nor by the means at his command.

Most of the arts reward the laborer, who engages in their pursuit,

with the attainment of his aim. But, though most of the arts do so, all do not. For, among that vast group of human activities to which the name of "arts" is applied, there are certain forms, the very essence of which consists in the seemingly unattainable character of their ends. And these activities, constantly striving for the absolute—for ideals of the many forms of beauty and of strength—are those known as the "Fine Arts."

But all the forms of the ideal world are a part of the religious system of a time, and for this reason all the fine arts have ever been in such close relation with religious belief. And, consequently, when we consider the essential and persistent characteristics of alchemy, such as its intimate connection with religion, and its endeavors to realize chemical ideals, we are compelled to regard alchemy as a primitive fine art, which fell into decay on account of the extreme inadequacy of its means, and the despondency of the artist. The true artist-hero, when he perceives that the absolute perfection he aims at is unattainable, save by the moral, intellectual, and technical education of successive generations, undismayed persists in creating, though not the ideal, yet at least beauteous forms, adumbrations of its image. The alchemist, when he saw that the prize was not to be attained in his day, ignominiously abandoned the field of action.

These facts point to a probability of the revival of alchemy in the future. But the conception of the perfectibility of matter is closely united to that of its transmutability. And when we inquire, "Has the chemical science of our time, by the unceasing toil of the last two centuries, not already developed the means which might enable us to successfully resume the great work of alchemistic art?" we receive not a favorable answer. Chemistry has taught us to resolve compounds into elements and to unite elements to compounds, but it knows naught of transmutation; all its inductions seem to disprove the existence of any reality corresponding to the idea. Year by year the belief that definite, specific forms of matter, such as water or iron, though resolvable or combinable, are yet in themselves absolutely fixed and invariable, has become more firmly rooted. And, if we would therefore hope to see the transmutation of imperfect forms of matter into others more perfect realized, it is not on the inductions and theories of chemistry that our hopes may be founded. It is among chemical conditions, and with the aid of chemical knowledge, that the future alchemist must resume his pursuit; but, before he may do so with any promise of success, these conditions and that knowledge must undergo a change, and chemical science, unleavened as yet by the thought which shall work it, must receive it from without.

The source whence this thought may be derived is the current of organic science, now distributing far and wide the fertilizing influence of the theory of evolution, a view of creation which, though not new,

was not victorious until, within the last decades, Charles Darwin led upon the hard-fought logic-field an array of facts glittering in their strength. Before a victory had been conquered by the Darwinistic school, the specific forms of vegetal and animal life were held to be immutable. While it was known that among the individuals of any one species certain differences, justifying their being classed as distinct varieties, might arise in the course of successive generations, all such variations were held to be bounded by certain more or less narrow limits of possibility. The facts adduced by the new school of biologists have led to different conclusions, culminating in the assertion that all organic forms are changeable without limit—transmutable without end—capable of a physical, intellectual, and moral elevation, which knows no boundaries.

According to the theory of evolution, the modifications of structure and capability which organic forms are liable to undergo, in the course of generations, may be traced back to three principal causes. The first of these is the influence of physical forces, as, when the strength of the muscles is enhanced by exercise, the mind invigorated by thought, or, inversely, their function impaired by long-continued disuse. The second cause consists in the transmission of these results of individual life to a line of descendants, the effects being compounded, as they pass, with others of the same order. The third cause is to be found in the competition of the forms so produced under circumstances not equally well adapted to their capacities nor sufficient for their coexistence, leading necessarily to the preservation of those races which are best, and the extinction of those which are least, fitted to endure adversity. To this last cause, constantly active in the organic world, the term "natural selection" has been applied, to distinguish it from the artificial selection of the stock-breeder and gardener. The changes wrought in organic forms by the influence of inorganic forces are generally spoken of as variation. But this variation is in reality merely an extension of the principle of competition. Organized beings are brought face to face with the forces of Nature, with the earthquake, the flood, the lightning, and the storm. Often they meet in mortal conflict. The living form sinks to the earth before the power of the thunder-bolt, or the thunder-bolt is conquered by the invention of genius. Death is but a victorious alliance of inorganic forces triumphing over the organic form laid low on the battle-field; life is but the victory of the organic forces over the inorganic hosts. But, do we not also behold a competition taking place between, a struggle for existence and a natural selection occurring among, inorganic forms? Cast water upon fire; either the water disappears as vapor or the fire is extinguished. A mixture of salt and gravel is brought in contact with water; the salt is dissolved, the gravel remains unaltered. Heat a mixture of salt and sal-ammoniac; the salt persists, while the sal-ammoniac is vaporized.

And here we may ask: "Is the distinction between that which is living and that which is not—between the organic and the inorganic worlds around us—properly drawn?" If the changes undergone by the forms of both are due to the same causes, wherein lies their difference? Both forms are capable of assimilating material from without; the organic by nourishment, the inorganic directly, as when a crystal grows by the assimilation of material from a solution in which it is placed. Both also are capable of producing offspring—at least by division if not by sexual genesis. Are we then justified in assuming the gap of distinction between these two orders of existence to be as wide and deep as it is generally considered? Life is the gradual modification of material forms by the action of physical forces; the continuity in time of the changes thus wrought; the competition of the forms thus evolved. It is the projection of the past into the future. It is the persistence of history.

And we may well question whether it were not better to extend our idea of life: Even if that wide gap which we imagine to open between the organic and the inorganic does exist, we may still ask: "Is the organic form the only living one, and the inorganic form so absolutely dead; or do they not rather both constitute forms of life radically and polarily opposed—vast alternate generations of existence, majestic in their mystery?" The power which fashioned this earth wrote not only upon the bark of the tree and the brow of man, but also upon the cold and passionless rock and the wide expanse of the deep, blue sea, their history. That which is seemingly so inanimate, as well as that which throbs with a warm consciousness of being, obeys the commanding influences of the past, and transmits them to the future. The biologist and the geologist have read the story; where they have not—the letters await but the riper wisdom of the yet unborn sage.

But the chemist has not yet acquired a knowledge of his historic alphabet. To him specific forms of matter are still immutable, unvarying, constant. He knows naught of differences wrought by the influences of the past, or of their transmission to the future. He is not aware of a competition or struggle for existence taking place between individual and specific forms of matter. The idea that substances, as we find them, are the result of a process of natural selection has been expressed, but it is as yet unsupported by experiment or interpretation of facts observed.

But, where a natural selection takes place, artificial selection is also possible; and, when chemistry shall develop before us the spectrum of the law of inorganic creation, the artistic spirit will seize upon the individual colors of truth, and once more endeavor to paint the image of the chemical ideal. The recognition of the law of evolution compels the acceptance of the inexorable conclusion that the competition of races must, in the course of infinite ages, inevitably lead to the ab-

solute perfection of the enduring forms. Natural selection this hope has been called, because the hand of Nature bestows the warrant of nobility. But man is himself only a part of that great, that bountiful, that all-generous Nature, and it is wrong to speak of the selections he has made among the flowers which embower his dwelling, and the half-mute companions of his home, as artificial. In making these he is but executing the commands of Nature, as the most skilled workman in her earthly palace of labor, and the approximations to perfection which she initiates by the intellectual and moral lever of his mind distance all others known to us.

The chemistry of to-day is, in part a science searching for forms of truth; in part an art pursuing the objects of the useful. The scientific chemist seeks and discovers realities of fact; the technical chemist produces realities of matter; neither of them endeavors to give existence to material ideals. But though man may thus unconsciously serve the inscrutable power through which all is that is, and all is what it is, yet of nobler mood is he who, feeling his heart swell in sympathy with her purpose—the creation of ultimate universal perfection—persists in constant faith to work her ends. Of such noble mood, and of such conscious purpose, must be the future alchemist. His work—the reformation of the crude earth, and air, and waters, that surround us, in the image of his chemical ideals, the production of untold varieties of the philosopher's stone—is not to be accomplished in a lifetime, or a century, but demands the continued labor of infinite generations. We shall never behold it, but—

> "On the day when, drawn on paths of duty,
> The last worlds—eternity-begun—
> Rest, embraced in ever-glorious beauty,
> On the heart of the All-Central Sun"—

shall most surely be witnessed its completion!

PROFESSOR LOUIS AGASSIZ.

By RICHARD BLISS, Jr.,
OF THE CAMBRIDGE MUSEUM OF COMPARATIVE ZOOLOGY.

LOUIS JEAN RODOLPHE AGASSIZ, whose death occurred the 14th of last December, was born May 28, 1807, in Mottier, Switzerland. From his earliest childhood he evinced a remarkable fondness for the study of natural science, and before he had left school began to collect and study into the habits of fishes. Having finished his course at the Gymnasium of Bienne, he chose for his profession that of medicine, and commenced to study at the Academy of Zurich. Thence he went to Heidelberg, where he made a special study of

anatomy. He next entered the University of Munich, where, in company with Martius, Oken, Döllinger, and Schelling, he devoted himself eagerly to the pursuit of natural history. At that time Martius was publishing his great work on the "Natural History of Brazil," and, upon the death of Spix, who was editing the zoological portion, Martius intrusted to Agassiz the description of the fishes. In this work, which was admirably well done, Agassiz characterized nine genera, embracing forty-two species new to science.

For some time Agassiz had contemplated a monograph on the "Fresh-water Fishes of Central Europe," but pecuniary embarrassment rendered this impossible, till a bookseller by the name of Cotta, to whom Agassiz showed the material he had collected, furnished him the means necessary for its completion. Meanwhile he studied and obtained the degree of Doctor of Medicine at Munich, and of Doctor of Philosophy at Erlangen. After his examination, Agassiz went to Vienna, and applied himself closely to the study of actual and fossil ichthyology. From Vienna he went to Paris, where he made the acquaintance of Cuvier and Humboldt, both of whom warmly welcomed this expert young naturalist. Here he lived on the most intimate terms with Cuvier till the death of that naturalist, in 1832, when he returned to Switzerland and established himself at Neufchâtel, where he was appointed Professor of Natural History, a position he held till his departure for America.

Through the influence of Humboldt, between whom and Agassiz there existed the warmest friendship, he was enabled to begin the publication of his "Poissons Fossiles," a work evincing such careful and profound research, and such a wonderful power of generalization, as to obtain for him a place among the very first naturalists of the day. This work, which appeared in parts, between the years 1833 and 1845, comprises five volumes, of about 1,700 quarto pages, with an atlas of 400 folio plates, and contains descriptions of nearly a thousand species of fossil fishes. Aside from the great number of species, genera, and families established, Agassiz adopted an entirely new system of classification. In the classification proposed by Cuvier, fishes were divided into two orders, according to the nature of the skeleton, viz., cartilaginous and osseous. Agassiz—looking upon the external covering of the animal as a reflex of the connection existing between the being and its surroundings, bearing the imprint of all the peculiarities of its existence, and consequently of its organization—deemed that the true principle of the classification of fishes was to be found in the scales. In view of this he proposed a division of the families of fishes into four orders, viz., *Placoids*, in which the scales are represented by plates of enamel, as in the sharks; *Ganoids*, in which the scales consist of angular bony plates covered with a thick layer of enamel, as in the garpikes; *Ctenoids*, or fishes with true scales, in which the posterior edges of the laminæ are toothed; and *Cycloids*, in which the scales are com-

posed of simple laminæ with smooth posterior edges. This last order Agassiz subdivided into Acanthopterygian and Malacopterygian Cycloids, or fishes having two dorsal fins, one spiny and the other soft, and those having one soft dorsal fin. Agassiz found that the study of fossil fishes exhibits a remarkable parallelism between the development of the individual and that of the class in geologic time. During part of the embryonic life of fishes, and even in some adult forms, the dorsal cord exists as a simple gelatinous cylinder, surrounded by a fibrous sheath, in which, after a time, there is found a cartilaginous and then an osseous deposit, which goes to form the vertebræ, the ossification taking place first in the apophyses. This embryonic character Agassiz found to be peculiar to the fossil fishes of the earlier geologic ages. There is no trace of a vertebra, but the apophyses, usually ossified, rest directly on the spinal cord.

Regarding the permanence of type, the author found the species of one formation specifically distinct from those of another, and, while it is impossible to say that the species pass from one into another, as they appear and disappear suddenly without direct connection with their predecessors, yet, as a whole, they present a continual progress of development, from the lowest to the highest, and demonstrate most palpably the existence of an ever-present directive intelligence.

Up to the end of the Jura epoch there exists among fishes a uniformity of type as well as a uniformity in the different parts of the animals themselves. The Placoids and Ganoids were the only fishes then inhabiting the seas; but, as we approach the Jurassic period which became preëminently the age of reptiles, we find a remarkable abundance of Sauroids, which, in their osteological character, the organization of their soft parts, and their dermal integuments, approach so nearly the reptile Saurians. At the end of the Jura period we find the Ganoids and Placoids giving way to the Ctenoids and Cycloids, which at present constitute the majority of our fishes. In the chalk-group, two-thirds of the species belong to extinct genera; in the inferior tertiary, one-third. In the Norfolk clay and Molasse formations the genera, for the most part, approach those of the tropical seas of the present day; and in the Geodian clay of Greenland there is found a species identical with one now living. In addition to the description of the species, which occupies the bulk of the work, a chapter is devoted to a critical review of the fishes of Monte Bolca, and another to those of collections in England and Scotland.

Agassiz next turned his attention to the study of Mollusca and Echinoderms, and in 1836 published a prodromus of the Echinoderms, and in 1837 a treatise on the fossil Echinoderms of Switzerland. In 1839 he began a more elaborate work, entitled "Monographies d'Échinoderms vivant et fossile," a most important contribution to modern zoology. This work comprises five parts: the first and second, on the *Salenies* and *Scutellæ*, by Agassiz; the third and fourth, on the *Galerites*

and *Dysaster*, by Desor; and the fifth, on the *Anatomy of Echinus*, by Valentin. Among the Scutellæ Agassiz found well-marked differences between the living and fossil species, and that all the species of the genera *Mellita*, *Rotula*, and *Encope*, belong to the existing epoch. He found, moreover, that the species increase in size as they approach the present period. While he was publishing his work on the Echinoderms, this indefatigable naturalist also described and figured a large collection of fossil shells from the Oölite and Cretaceous formations, in a work entitled "Études critique sur les Mollusques de Jura et de la Craie," besides an annotated German translation of Buckland's "Geology," and French and German translations of Sowerby's "Mineral Conchology."

Notwithstanding the immense amount of work on his hands, Agassiz found time to prosecute his investigation upon the fresh-water fishes of Europe. The first part of this work, issued in 1839, is devoted to the genera *Salmo* and *Thymallus*. It appears as a folio of twenty-seven excellent plates, with descriptions illustrating six species of Salmo and one of Thymallus, one plate of each species being colored according to life, the others representing differences of age, sex, and locality. The second part, which did not appear till 1842, consists of a folio of plates and a volume of text on the "Embryology of the Salmons," by Carl Vogt, whom Agassiz had associated with him in his work. M. Vogt has given the most detailed descriptions and figures of the different organs, and the changes they undergo from the formation of the cellules, out of which the organs are developed, to the adult state. In regard to cell-formation, M. Vogt differs from Schwann in affirming that the germinative vesicle is formed prior to the nuclei and nucleoli. The volume closes with a history of the daily development of the embryo, from the exclusion of the egg to the birth of the young. This excellent work was never completed; Agassiz's departure for the United States shortly after, and his increasing responsibilities, prevented the perfection of his orignal plan.

In 1842 Agassiz began the publication of his "Nomenclator Zoologicus," an alphabetical list of every genus, with the name of the author, the work in which it originally appeared, the derivation of the name, and the family to which the genus belongs; the list embracing upward of seventeen thousand names. In the introduction the author examines the rules proposed by the British Association and those of the British Committee. He agrees with the rules proposing that the name given by a founder of a group, or the first describer of a species, should be retained, and that priority is to be conceded only to a name published in some universally accessible work. On the other hand, he objects to the restriction of priority to Linnæus and to the rule that would change a name previously in use in connection with some other genus in zoology or botany, as this would result in the sacrifice of half the names of recent times. He does not think it wise

to discard *barbarous* names, and, when a species becomes the type of a new genus, he would retain the former specific name as the generic appellative. He objects to the use of small initial letters for substantives borrowed from persons or places, to the uniform restriction of family and sub-family terminations to *idæ* and *inæ*, and strongly condemns the proposition that the name of the original propounder of a species should be retained when the species is transferred to a different genus. He likewise condemns those who would change the authority for a genus when the name is changed through faulty orthography, and censures the use of vernacular names in scientific works to the exexclusion of the systematic ones.

The "Fossil Fishes" was now approaching completion, but, in consequence of additional material, Agassiz determined to publish a supplement; and accordingly there appeared, in 1844, the "Fossil Fishes of the Old Red Sandstone." It was accompanied by an atlas of thirty-nine folio plates illustrative of the seventy-six species described. The author, after discussing the relative rank of the members of the various classes of the animal kingdom, and showing how closely the time of their appearance on the earth corresponds to their relative standing in their respective classes, announces the conclusions to which a study of the fishes of the Devonian system had led him. These fishes actually represent the embryonic age of the Reign of Fishes, undergoing "phases of development analogous to those of the embryo, and similar to the gradations which the present creation shows us in the ascending series it presents when viewed as a whole." The members of the five families whose species he describes, are characterized by the absence of distinct vertebræ, the apophyses resting on the spinal cord, and by the absence of ossification in the internal case of the cranium. In these characters, as well as in the peculiar development of the vertical fins, the heterocercal tail, the flattened form of the head, and inferior or sub-inferior mouth, we see peculiarities of structure common to the embryo and the lower forms of existing as well as paleozoic fishes. This affords us a key to the relative rank of these fishes, for we find the *Cephalaspides*, which recede most from the existing forms, confined to the Devonian. The *Sauroids*, which are represented only by a particular group—the Dipterians—are likewise confined to the Devonian. The *Acanthodians* become extinct at the end of the Chalk, while the *Cestraciontes* persist to the present epoch. The same year Agassiz also read before the British Association a "Report on the Fossil Fishes of the London Clay."

Of all Agassiz's investigations, perhaps none made his name more popularly known than his studies on glaciers—studies which were pursued through a long course of years, and conducted with the same painstaking care that had heretofore characterized all his labors.

About the year 1834, M. Charpentier advanced the theory that the erratic blocks, and certain dikes of peculiar shape found in the

Alpine regions, were the result of the action of former glaciers descending from the Alps and reaching even the upper portions of the Jura. This theory Agassiz deemed improbable, till, having visited Charpentier and investigated the phenomena, he not only became convinced of the correctness of Charpentier's views, but deduced from these and other phenomena a theory which, at the time (1837), was startlingly novel. It was that, previous to the elevation of the Alps, the globe experienced a very great reduction of temperature, and that the appearance of those mountains found the surface of the globe, from the north-pole to the Mediterranean Sea, covered with an immense sheet of ice. An elevation of temperature, consequent upon the upheaval of the Alps, caused this ice slowly to disappear, remaining longest in the valleys, where it gradually retreated to its present limits, leaving behind it, as a record, the peculiar phenomena which have attracted the attention of so many observers.

Of course a theory so novel at once raised a storm of opposition, and it became necessary for Agassiz, if he would prove the correctness of his views, to make the most careful and thorough investigations on living glaciers. For this purpose Agassiz, in company with Desor and several others, made visits in 1838 and 1839 to the glaciers of Mont Blanc and the Bernese Oberland, and in 1840 established himself for the summer on the glacier of the Aar. That year he published his "Études sur les Glaciers," giving the results of his investigations up to that time. He also visited England, Scotland, and Ireland, and studied the evidences of ice-action in those countries.

But his labors were not finished. Doubting the sufficiency of the theory of De Saussure—that the cause of the motion of the glacier depends upon gravity—and inclined to accept the dilatation theory of Schenchzer, it became necessary for him to examine with care the structure, form, distribution, and rate of motion of the glacier. Thus it was that, in 1841, he began a second series of observations for the purpose of determining these points. He chose, for the theatre of his investigations, the glacier of the Aar, which, by its extent and accessibility, promised the most favorable results. In 1845 he had completed his work, and in 1847 appeared his "Système Glaciaire," which embodied the final results of his researches upon the structure of glaciers, and their effects upon the soil. The results at which he arrived may be summarized as follows: The glacier is a mass of ice reclining on the side of a mountain-ridge, or inclosed in a mountain-valley; it is always descending, and, while wasting away from heat at its lower extremity, is continually augmented at its source. The primary material of glacier-ice is the snow which falls in the high regions of the mountain. The yearly addition of snow in the higher cold regions gradually forces the snow down the valley; here, subject to alternate thawing and freezing, it undergoes a second crystallization into what is called *névé snow*, and still farther down, under increased pressure, be-

comes transformed into a granular, opaque, bulbous ice, called *névé ice*, which at last changes into the compact blue ice of the glacier proper.

During the summer, when the snow-fall is at its minimum, the surface of the snow in the high regions becomes covered with dirt and sand, which the next winter covers with another snow-sheet. In summer these layers of snow, from a partial melting and subsequent freezing, become changed to ice on their surfaces, so that we have three kinds of deposits—beds of snow, sheets of dust, and layers of ice. As the whole is pushed down into the valley, these layers tend to assume a vertical position from the bottom of the mass, moving faster than the top; and, the snow in summer melting from the surface as far as the snow-line, the edges of the layers are found passing transversely across the glacier. The middle of the glacier being deeper, moves faster than the sides, and, the lower layers advancing more rapidly than the upper ones, the strata become curved forward, the lower layers being more sharply arched. The arch thus becomes the measure of the rate of movement in the different parts of the glacier. From this it will be seen that Agassiz dissents from the theory of Tyndall, which represents the stratified lines as due to *ice-cascades*, or breakages of the glacier in passing over sharp angles.

All glaciers exhibit numerous blue bands, which are parallel to the planes of stratification, and are formed by thawing and freezing, and by the vertical pressure of snow in the *névé*. Moreover, there are found certain veined structures of the ice which appear to be bands of infiltration, and intersect the planes of stratification at every possible angle. As they are most numerous at the sides of the glacier, it is probable that Tyndall's theory of internal liquefaction of ice by pressure may account for them.

In the progress of the glacier, its rate of movement is not uniform, the differences between the centre and the sides being about as ten to one. Neither is the motion uniform along the axis; the advance being greatest about half-way down the region of the *névé*, and diminishing in rapidity both above and below. Agassiz found that it was from 20 to 50 feet per year in the higher portions, about 250 feet in the *névé*, and diminishing again lower down.

The causes of the movement of the glacier are several. The weight of the glacier alone is not sufficient to propel it, as in this case the greatest movement would be in the winter, which is not the case. The principal agent is the infiltration of water, which is greatest when the winter snows are melting. The granular snow of the *névé* incloses numerous particles of air, which, when the snow is compressed into ice, form a net-work of capillary fissures that serve as canals of infiltration, the water in which, freezing, aids in propelling the glacier. Added to this may be such other causes as the weight of the mass, the pressure of accumulated snow above, the weight of infiltrated water, and the softening of the ice by water, and a consequent sliding along the surface.

The sides as well as the bottom of the glacier are studded with bowlders, pebbles, and sand, forming a gigantic rasp. As the glacier moves forward, this rasp grinds, furrows, and polishes the rocks over which it moves, the furrows trending in the direction in which the glacier moves. These furrows and polished surfaces, which are often observed on rocks remote from any living glaciers, are the record of the former existence of glaciers in such places. When the ground is uneven, the eminences being small, and the hollows too deep and wide to be bridged over by the glacier, the ice-rasp rounds and polishes these knolls, forming those rounded elevations which have received the name of *roches moutonnées.* In consequence of the rocky walls above the sides of the glacier becoming warmed by the sun, the ice is melted near them, and hence the glacier becomes convex. Into these troughs the *débris* from the walls fall and form long lines of bowlders, pebbles, and sand, which are called *lateral moraines.* When two glaciers flow together, the two lateral moraines on the adjoining sides of each unite and form what is called a *medial moraine.* A third form, the *terminal moraine*, is the accumulation of sand and rocks which the glacier pushes before in its progress down the valley. In consequence of the increased rate of progression of the centre of the glacier, these terminal moraines assume a semicircular form, which, when the glacier retreats, consequent upon an excess of liquefaction over the snow-supply, leaves a crescentic wall across the valley, usually cut in two by the river flowing from the glacier. The erratic blocks which are found over most of the globe, accompanying scratched and polished rock-surfaces, are simply the bowlders of the surface of the glacier left on or near the spot where they stood when the glacier disappears.

In the fall of 1846 Agassiz sailed for the United States, on a mission from the Prussian Government. The warm reception which greeted him here, and especially the rare field for scientific research which this country afforded, determined him, the next year, to make America permanently his home. The professorship of Natural History in the Lawrence Scientific School at Harvard College being offered him that same year, he accepted it, and held the position till his death, with the exception of two years when he occupied the chair of Natural History in the University of South Carolina, at Charleston. In 1848, in connection with H. E. Strickland, he began the publication of a "Bibliographia Zoologiæ et Geologiæ." This work, which comprises a list of all the periodicals devoted to zoology and geology, and an alphabetical list of authors and their works in the same departments, was completed in four volumes, the fourth being published in 1854.

Agassiz's studies on the glaciers of Switzerland led him to expect to find in the United States many traces of former ice-action. Nor was he disappointed. He explored the country from the Atlantic to the Rocky Mountains, from the great lakes to the Gulf of Mexico, and everywhere, north of the thirty-fifth parallel of latitude, found evi-

dences of glacial action, in erratic blocks, polished and striated rock-surfaces, and terminal moraines. Naturally this served to confirm him in his belief in the universality of the ice-period; and, upon his departure for Brazil, in 1865, he announced his confident expectation of finding records of the former existence of glaciers in that country; for, according to his belief, not only most of the Northern, but also most of the Southern Hemisphere was, during the glacial epoch, encased in ice. The evidences of glacial action in the United States are fully discussed by Agassiz in his "Lake Superior," a work on the physical character, vegetation, and animals, of Lake Superior, compared with those of other and similar regions.

Agassiz was a firm believer in the diversity of origin of the human race, and his views on this point are ably presented in the *Christian Examiner* for July, 1850, and in an introduction to Nott and Gliddon's "Types of Mankind." While denying the unity of origin of the races of mankind, he by no means denies their essential unity as one brotherhood. He regards all races of men as possessing in common the moral and intellectual attributes of humanity which raise them above the brutes. But intellectual relationship does not imply community of origin. The geographical distribution of animals shows that distinct zoological provinces are each characterized by peculiar fauna, and that therefore animals did not originate from a common centre nor from a single pair. The races of men, in their natural distribution, cover the same ground as the zoological provinces, and he believes there is every reason to suppose that these races originally appeared as nations in the regions they now occupy. That the differences at present observed between various races are primitive, and have not been the result of modification from one common ancestral type, he believed is evidenced by the monuments of Egypt, which show that, for 5,000 years, there has been no physical change in the negro and Caucasian.

In 1850 there appeared in the Transactions of the American Academy of Arts and Sciences an article on the naked-eyed Medusæ, being Part I. of Agassiz's "Contributions to the Natural History of the Acalephæ of North America." He includes all the naked-eyed Medusæ in one family, and shows that the number of tentacles and the position of the ovaries alone cannot be considered as family characters. The true characters consist in a gelatinous disk, with a re-entering margin, along which passes a submarginal tube connecting with the circulatory tubes proceeding from a central digestive cavity. Upon the margin are the tentacles and eye-specks. The reproductive organs are situated along the circulatory tubes. The generation is alternate, one form being polyp-like, the other medusoid. The nervous cord follows the circular submarginal tube, and consists of several rows of nucleated cells, alternating one with another. It passes into the bulbs at the base of the marginal tentacles, in which are situated the eye-specks. A branch of nerve-thread passes also along each of the

radiating circulatory tubes to the digestive cavity. The circulatory fluid is chyme, and not chyle, as it is in the Articulata and Mollusca. The author describes four species, and distinguishes a new genus—*Nemopsis.*

Ever since his arrival in America, Agassiz had been collecting material for a series of "Contributions to the Natural History of the United States." In 1857 appeared two volumes of these contributions; the first containing an "Essay on Classification" and the history of the North American Testudinata; the second on "the Embryology of the Turtle."

In the essay on Classification, Agassiz affirms that Nature is but the expression of the thought of the Creator, and that a true classification will be found to be but an unfolding of the plan of creation, as expressed in living realities; that these realities do not exist in consequence of the continued agency of physical causes, but appear successively by the immediate intervention of the Creator. We find in Nature a progressive series, from lower to higher forms; but it is not a uniform progress for the animal kingdom as a whole; neither is it a linear progress for the branches or classes, but a progress in which each type has usually been introduced by the creation of species belonging to one of its higher groups, for the earliest representatives of a class do not always seem to be the lowest. Yet, notwithstanding these downward steps, the progress has continually tended toward the production of higher and higher types, culminating at last in Man.

We find a parallelism between the geological succession of animals and the embryonic growth of their living representatives, as well as a parallelism between the geological succession of animals and their relative rank. The earlier types of animals were synthetic or prophetic, foreshadowing a future group. Types likewise culminated and disappeared in past ages—a feature parallel with the fact that in embryological development parts fulfill their end and then disappear.

Regarding Nature as the embodiment of a certain divine plan, Agassiz sought for a classification that should be the expression of this plan. Accordingly he based his classification on the following divisions, which he deemed covered all the categories of relationship, as far as their structure is concerned: *Branches*, or types characterized by their plan of structure; of these, he admitted four, Vertebrates, Articulates, Molluscs, and Radiates. *Classes*, which are characterized by the mode of execution of the plan. *Orders*, by the degree of complication of structure. *Families*, by the form as determined by structure. *Genera*, by the details of execution; and *Species*, by the relation of the individuals to one another, and to the world in which they live.

In Part II., Agassiz believes that the Testudinata constitute an order among the class of reptiles; that their essential character lies not so much in the shield as in the special development of different regions of the body, thus giving them the highest rank in the class.

The shield is partly a portion of the skeleton, and partly an ossification of the skin or of the walls of the body.

The second volume treats entirely of the embryology of the turtle, and is illustrated with thirty-four plates. The egg originates from between the cells of the stroma, and is in itself the animal in the first stages of development. The eggs are laid once a year, and grow a long time before they are fecundated. From the first copulation to the laying, four years elapse, during which time eight copulations take place. The segmentation of the yolk takes place during the passage of the egg through the oviduct. From the segmentation of the yolk to the period of hatching, the egg passes through thirty-one stages of development.

The third volume of the "Contributions" appeared in 1860, and was devoted to the class of Acalephæ, the author treating specially of the order *Ctenophoræ*. The *Ctenophoræ* Agassiz divided into three suborders: the *Eurystomæ*, embracing three families, the *Saccatæ*, with three families, and the *Lobatæ*, with five families. The fourth volume of the "Contributions," in 1862, concluded the Acalephæ, treating of the *Discophoræ*, *Hydroidæ*, and the *Homologies* of the Radiata.

Of the more recent labors of Agassiz in connection with the Museum of Comparative Zoology at Cambridge—of which he was the director, and to which, in later years, he devoted his whole attention—it is not necessary to speak. With his journey to Brazil in 1865, and his later expedition from Boston to San Francisco on the United States Coast Survey steamer Hassler in 1872, the public is already sufficiently familiar. His last days were devoted to the cause of education, in the establishment of a school of natural history at Penikese Island.

Of the man himself but a word is necessary. As a naturalist, Prof. Agassiz was unwearied in his devotion to his favorite pursuits. He worked early and late, often denying to himself the most necessary rest and recreation; and his remarkably strong constitution sustained him under a strain that would quickly have proved fatal to a man of less vigor. His mind was preëminently great; gifted with a wonderfully retentive memory, he combined with it a power of generalization and quick perception that places him next to Cuvier, whose disciple he was, and whom he seemed to imitate. In his methods of investigation he was perfectly honest, and, though many might differ from him in his conclusions, none could deny the absolute integrity of his convictions. In his intercourse with his fellow-men he was extremely affable and genial, and especially so toward the young. With inexperience he was most patient and painstaking, never wearying in his efforts to aid. Tolerant of ignorance where associated with modesty, he had but little patience with arrogance and ignorance combined. His students will all bear witness to the unvarying cheerfulness and ready sympathy in him they had learned to look up to as their master.

EDITOR'S TABLE.

INFLUENCE OF SCIENCE UPON PHILOSOPHY.

IN his thoughtful little work on "Recent British Philosophy," Prof. Masson, of the University of Edinburgh, has the following suggestive passages upon the subject indicated in the present title:

"However earnestly we may contend for such a notion of Philosophy as shall keep up the tradition of it as something more than Science, yet the perpetual liability of Philosophy to modifications, at the hands of Science, is a fact obvious to all. Not a new scientific discovery can be made, not a new scientific conception can get abroad, but it exercises a disturbing influence on the previous system of thought, antiquating something, disintegrating something, compelling some readjustment of the parts to each other, some trepidation of the axis of the whole. Sometimes the action is almost revolutionary. What a derangement in men's ideas about every thing whatsoever, what a compulsion to new modes of thinking, and to new habits of speech, must have been caused by the propagation of the Copernican Astronomy! What a wrench to all one's habits of thought, to be taught that the little ball which carries us rotates on itself, and is one of a small company of celestial bodies that perform their periodical wanderings round the sun, in lieu of the older astronomical faith, according to which the earth was fixed in the centre, and the limitless azure with its fires was one vast spectacular sphere, composed of ten successive and independent spherical transparencies, made to wheel round the earth diurnally for her solitary pleasure! Man's thoughts, even about himself and his destinies, could not but be changed in some respects by this compulsion of his imagination to a totally new way of fancying physical immensity and our earth's share in its proceedings. . . .

"It is not every day, indeed nor every century, that there occurs such a vast compulsory shifting of the very axis of men's conceptions of the physical universe as that which our ancestors had so reluctantly to submit to only a century or two ago. But every generation, every year brings with it a quantum of new scientific conceptions, new scientific truths. They creep in upon us on all sides. Is Philosophy to stand in the midst of them haughtily and superciliously, taking no notice? She cannot do so and live. Whether she knows it or not, these are her appointed food. She must eat them up or perish. They do not constitute her vitality, any more than the food that men eat constitutes the life that is in them; but, just as men, in order merely to continue alive, must refresh themselves continually with food, so Philosophy, that she may not fall down emaciated and dead by the wayside, must not only not hold aloof from Science, but must regard what Science brings as her daily and delicious nutriment. Whatever definition of Philosophy we adopt—whether we call it simply and beautifully, with Plato in one passage, 'a meditation of death,' or adopt some of the more labored definitions that have been given expressly to indicate its relations to Science—it is equally certain that a philosophy that should be out of accord with any ascertained scientific truth or tendency to truth, or that should not in some efficient manner harmonize for the reason all the conceptions and informations of contemporary science, would be of no use for educated intelligences, and would exist as a refuge for others only by sufferance. Shall Philosophy pretend to regulate the human spirit, and not know what is passing within it—to supervise and direct man's thinkings, and not know what they are?

"In no age so conspicuously as in our own has there been a crowding in of new scientific conceptions of all kinds to exercise a perturbing influence on Speculative Philosophy. They have come in almost too fast for Philosophy's powers of reception. She has visibly reeled amid their shocks, and has not yet recovered her equilibrium. Within those years alone which we are engaged in surveying there have been developments of native British science, not to speak of influxes of scientific ideas, hints, and probabilities from without, in the midst of which British Philosophy has looked about her scared and bewildered, and has felt that some of her oldest statements about herself, and some of the most important terms in her vocabulary, require reëxplication."

The truths here enunciated cannot be too carefully pondered. In its modern progress Science has been constantly warned off from the field of Philosophy, as having no concern whatever with its issues or interests. But Science has no more choice or responsibility in regard to the results of its work than it has with regard to the phenomena which it investigates. If it is to be suffered to exist at all, it must proceed with its labor of investigating facts and establishing principles; to what conclusions these will lead depends upon nobody's preference, but upon the constitution of the universe itself. If the scheme of being around us is a harmonized and unified order, where all the parts are in reciprocal sympathy, then he who strikes an impulse is not to be called to account for the sweep and compass of the undulations which follow. Science may be occupied in her legitimate duty with simple laboratory experiments, and establish results that will thrill through all spheres of thought, and reach to the very core of philosophy.

Such a step was taken in the last century in establishing the indestructibility of matter. The problem that had baffled philosophy, for thousands of years, was settled by the experimenters. The truth which was inaccessible to speculation was arrived at by the physicists and chemists. It had been believed, for centuries, that in the changes of form—the appearances and disappearances of Nature—existence itself was implicated, and matter, the substratum of being, was continually created and destroyed. The poetic divination—

> "The eternal Pan,
> Bideth never in one shape,
> But forever doth escape
> Into new forms"—

only became a demonstrated truth when the mechanics had perfected the chemical balance and made it possible to pursue the course of material transformations. It was then found that the old belief in the destructibility of matter was without foundation, and that the persistence of material elements through all changes of form was demonstrated by every particle of evidence that bore upon the case. Philosophy, which aims at the deepest explanation of the order of things around us, if it has any aim worth pursuing, thus derived a new datum from the workshop; but how foolish to assume that, in elaborating it, the chemists were inspired with any purpose to trench upon the domain of Philosophy!

But this research, which ended in the establishment of the law that matter is indestructible, was but an apprenticeship for deeper and more delicate investigations of the same kind. The use of the balance led to the discovery of quantitative chemistry, the highest phase of the science, and strengthened the mental habit of regarding phenomena in their quantitative relations. Matter is not only associated with forces, but it is manifested and known through its essential and inseparable activities. It is not only determined by its forces, but it is measured by them. The very instrument by which matter was proved to be indestructible, was but a device for showing the constant relation of material bodies to the force of gravity. Cohesion, affinity, heat, light, and magnetism, are but dynamic affections of matter, which are involved in all its changes, and it was simply inevitable that when one element of things was proved to be essentially indestructible, through every mutation of form, the same inquiry should be pressed in regard to this character of the other forces. Naturally, and quite necessarily, the disciplined scientific thinkers of different countries, with no knowledge of each other's purposes, and proceeding from different points of view, were led to engage with the experimental problem of the quantitative interactions of

the molecular forces. The consequence of this was another step forward, of the greatest possible importance. It was shown that the physical forces are as obedient to quantitative laws as matter itself had been proved to be, and that, while they are mutually convertible into each other, force, like matter, is indestructible in its nature. The various forms of energy by which effects are produced in the surrounding world, although changing incessantly, were discovered to be never created and never annihilated. With the evidence that every form of force is derived from some preëxisting form of it, the hope of a mechanism generating its own power perpetually, passed away among impossibilities, and the science of forces became limited to problems of transformation. It was much to have exploded the fallacy of the perpetual motion, upon which the ingenuity and wealth of generations had been wasted, but it was far more to have seized upon a principle of Nature which Dr. Faraday could pronounce to be the highest law in physical science which our faculties permit us to perceive. And are the discoverers of this principle to be held accountable for the reach and play of its applications? No doubt a law of Nature's activities, thus supreme and far-extending, cannot be limited to the field of physical phenomena. The probabilities are strong that, wherever effects are produced in degrees of more or less, they are strictly conformable to quantitative conditions, although the proof of it may be indirect and difficult, and exact results quite unattainable. But with this point we have here no concern, and only say that it is no business of Science if the law be found to pervade domains of thought which Philosophy has hitherto claimed to be exclusively her own. Nor is there any just ground for arraigning men of science as transgressing the proper limits of their inquiries by pursuing the principle of the conservation of energy into the spheres of life, mind, and social activity. Science could not evade the necessity of entering upon the earlier steps of the investigation, any more than it can now evade the necessity of pursuing it; and it would be a worthier proceeding on the part of philosophers, gratefully to accept what she contributes for their use, rather than to raise an outcry against the scientists for interfering with matters which, it is assumed, do not belong to them.

ANOTHER "SPENCER-CRUSHER."

The work of putting down Herbert Spencer, which has been going on these dozen years, still flourishes and threatens to become a regular occupation. Obscure men are making reputations right and left, and famous men are adding to their laurels by taking down the great philosopher on all sides. If they do not succeed in getting him out of the way, this branch of criticism may grow into a thrifty business. Who shall be greatest in this little but increasing kingdom of criticism, it is as yet premature to say, although symptoms of gradation in the honors of the work are beginning to be disclosed. We explained, some time since, in the Monthly, that our friend Liefchild had brought forth a big book, which was evidently designed to interrupt Mr. Spencer's philosophical career. He did not, however, himself aspire to the distinction of wiping him out, but assigned that high function to President Porter, of Yale, whom he ranked as the great "Spencer-crusher." Mr. Liefchild would probably accord to others the minor grades of extinguishers, upsetters, depressers, etc. Meantime the work may be expected to proceed vigorously. Although we often hear that Mr. Spencer has at last been quite demolished and put an end to, he seems to be still alive and in a very vigorous condition, as the article replying to the *Quarterly* Reviewers in our present number will

attest. The last aspirant for glory, in the Spencer-crushing line, is one Alexander Gibson, hitherto guiltless of fame, whose onslaught is contained in a late number of the London *Academy*. This periodical, it may be remarked, was started a few years ago, with an Oxford parentage, as an organ of old rubbishy scholarship and useless lore generally, and, having been knocked about among different publishers as a bad speculation, now turns up in new hands, and the transition is signalized by the present essay at the use of the critical scalping-knife.

Conscious, perhaps, of the trouble he has been causing to the critical fraternity, Mr. Spencer has lately changed his tactics. In his former works he expressed his own opinions very freely on various subjects, and it is these that have been the objects of attack by the increasing crowd of his assailants. They have shown, in a manner perfectly conclusive to themselves, that his views are weak, foolish, erroneous, false, absurd, dangerous, and wicked. And so he has now made a book containing no opinions of his own at all. It is a work simply of facts and authorities, and, as if scrupulously to avoid rousing the ire of his enemies, he hired a man to write out the facts and copy the authorities. His own agency was limited barely to drawing up a plan of presentation, which his assistant was to follow, and he indulges in not a word of comment upon the statements that are made. But all in vain. Alexander Gibson hunts him out, even in this city of refuge, and is bound to crush him all the same. Let us gather up the fragments, and see what remains after this last assault.

In reviewing the "Descriptive Sociology" in the *Academy*, Mr. Gibson makes two points, which are—*first*, that the compilation of facts by Spencer's assistant, Mr. Collier, is badly done; and, *second*, that, if it had been well done, the work would still be good for nothing.

Mr. Gibson begins by a representation that is quite misleading. He says: "It is clear at a glance that the work thus undertaken is one of great magnitude and difficulty; and, when one considers the high reputation Mr. Spencer has acquired by his sociological theories, it acquires a peculiar interest, as it will serve to show the nature and value of the material which he has used for constructing or testing his speculations." The implication here is, that Mr. Spencer has first theorized and speculated upon social questions, and then sought for facts to support his views. But Mr. Spencer's social philosophy has never yet been developed, and the collection of sociological data which was commenced five years ago is designed as the foundation for general principles yet to be derived from them. The relation of these materials to the uses for which Mr. Spencer himself proposes to employ them cannot therefore be judged until his principles of sociology are worked out. Mr. Gibson inverts the truth of the case, for Mr. Spencer's extensive collection and classification of facts were not made to sustain past speculations but as a guide to future theories.

In judging of his undertaking, it is important to remember that Mr. Spencer published first that division of it which is most open to criticism; that is, he deals first with the social elements of his own country, the history of which is generally familiar. It is also not to be forgotten that his aim was to bring forward just that order of facts for which historians have cared the least, and concerning which their statements have been most loose, careless, and conflicting. Added to this, the work of collection and arrangement had never before been attempted, and Mr. Spencer had to work as a pioneer in the field. It is also noteworthy that the plan of the work precluded all explanatory comment. That such a work —a work of "great magnitude and

difficulty," as Mr. Gibson allows—cannot be free from errors is obvious, and from all the foregoing causes it is peculiarly exposed to unscrupulous criticism. When these considerations are taken into account, Mr. Gibson's case of alleged errors in the tabular statements on the part of Mr. Collier is simply pitiful. His six-column search for flaws and defects yields the following outcome.

Mr. Collier enters his numerous and varied facts in their proper relations in the tables in the most condensed language possible, as he was compelled to do by the nature of the presentation; but this, of course, affords Mr. Gibson an opportunity, which he duly improves, to complain of the want of explanations. For the classified facts Mr. Collier gives in the accompanying text the exact words of the authorities which he has followed, and Mr. Gibson has no admiration for disjointed "scraps." Mr. Collier has made quotations from about one hundred and seventy works, which were of course sought as the best, and which the intelligent reader will see comprehend the great mass of authentic English history. Mr. Gibson impeaches none of these authorities, but sublimely discredits the whole, declaring that they "are not, in the historical sense of the word, authorities at all." This, of course, is mere assertion. The "historical sense" can be nothing else than common-sense applied to history, and that can only require the compiler to seek the best possible sources of information. If the regular historians have failed to furnish it, it must be gathered from other and scattered sources. Mr. Spencer's tables give strong evidence of being a faithful reflex of the social state. They are full of gaps where information could not be supplied; and the best authorities extant have been diligently searched for the statements, names and pages being carefully given; what more can be reasonably asked? Although he does not attempt to show wherein the authorities are untrustworthy, he tries to make out three or four instances in which the quotations are insufficient to justify the statements based upon them in the tables. Again, he says there is no clear trace that he (Mr. Collier) has any perception of the relative value of the different facts he has come across in the one hundred and seventy volumes which he has consulted. It is but just to Mr. Collier to say that, while he has *quoted* one hundred and seventy volumes, he has *consulted* a far larger number, and it is a sufficient reply to Mr. Gibson's insinuation regarding Collier's defective "perception" of the relative values of his facts, that their valuation was not his business, and if some are more valuable than others he could not very well help it. Mr. Spencer has pointed out in his preface the difficulty of reducing such multifarious details to a tabular statement in parallel columns, while the advance of society constantly gives rise to new elements. The exigencies of the classification required that, to a certain extent, diverse though kindred facts should be grouped together. But this does not protect him from the hypercritical Gibson, who carps at the distributions, and thinks that "most of the information under the head 'Morals' ought to be transferred to the heading of 'Law and Politics;'" while the diversity of objects that Mr. Collier has included under the head of "Tools and Implements" is gravely pointed out in the array of objections. Of Mr. Collier's omissions this keen-eyed critic has discovered one which he duly chronicles: it is the failure to mention "dramatic poetry." Mr. Gibson is captious over the deficiency of the statements, and thinks that more facts are wanted. He says: "It would be the merest impertinence for Mr. Spencer's sociological student to draw conclusions from such miserable data

as, for example, are afforded, in the case of English religious ideas and superstitions from the Druids to the Gorham controversy, within the limits of seven columns an inch wide." Yet, in these seven long columns of compressed statements, with the copious authenticating extracts, there is a vast amount of valuable (though we suspect to Mr. Gibson), of unpalatable information, as he returns to them again and again with unhappy comments. But it is to be remembered that Mr. Spencer is far from proposing to formulate a sociological science on the basis of English experience alone. The plan of his work embraces all types and grades of the social state, and is so comprehensive that its complete publication is still a matter of question. Mr. Gibson's complaints at the paucity of the materials are, therefore, quite gratuitous.

Such is the quality of Mr. Gibson's critical work. It is approached in an ugly temper, and, a few petty inaccuracies and defects being found, the most absurd charges are made and the whole work declared unworthy of confidence. The complete break-down of his case, so far as Mr. Collier is concerned, affords excellent evidence of the judgment and fidelity with which the task has been executed.

Mr. Gibson's second point is that, "even supposing that Mr. Spencer had got them (the tables) done with as great accuracy and intelligence as possible, they would still be useless." But why expend so much vicious ingenuity in finding defects in an intrinsically worthless thing? One would naturally suppose that this second point would have been taken up first, because, if established, the former inquiry would be superfluous. But, if we ask for the reasons of this position, Mr. Gibson wisely declines to give them; only remarking that "we have had too much already of the tendency, on the part of framers of social and other sciences, to deal superficially with history." By the framers of sciences, we suppose that Mr. Gibson can only mean those cultivators of science who originate and organize this kind of knowledge, and the upshot of his charge, therefore, is that the scientific method of studying history is superficial. This raises the question, "What are the depths, and what the shallows, of history?" Of the descriptive sociology, one of the most eminent authorities in England, Mr. E. B. Tylor, writes in *Nature:* "So much information, encumbered with so little rubbish, has never before been brought to bear on the development of English institutions." Is it the information concerning the "development of English institutions" that is the superficial element? and is it the "rubbish" that constitutes the profound element wanting in Mr. Spencer's plan? There are two methods of dealing with history: the old method of chronicle, narration, and story-telling, which was in vogue before science arose; and the later or scientific method, which aims at the discovery of natural laws among historic phenomena. The old method occupied itself with the registration of surface effects, and whatever happened to be uppermost and obtrusive in any place or period. It was a biography of the conspicuous figures that chanced to emerge and occupy passing public attention. It was full of the doings and sayings of sovereigns, generals, diplomatists, and politicians; full of their gossip, rivalries, and crimes; the details of war, the quarrels of factions, and the intrigues of ambitious families; and it has consisted of so chaotic and incoherent and interminable a mass of details of this sort, that its cultivators scout the idea that there is or ever can be any thing like a science of history. This, we suppose, is to be taken as the deep part of the subject—its profundity being due to the fact that it cannot be reduced to order? On the other hand, science, which has disclosed the opera-

tion of law throughout all the workings of Nature, has entered with its new method upon the study of society. In what does the social structure consist? what are the nature and laws of its activities? what are the conditions of its development? These are its problems. Science always begins with the observation, determination, and classification, of facts. This is its first solicitude. To get at the facts with the highest certainty and the greatest exactness and fullness that are possible, is the primary and inexorable duty of the true scientific inquirer. To put these facts in their proper relations, so as to draw from them the principles and laws by which they are governed, is the essence of scientific method, and to this Mr. Spencer has rigorously conformed by devoting a separate and extensive work to the systematized data that are necessary for valid reasoning upon social subjects. All this, says Mr. Gibson, is of no use, because, if it is "done with as great accuracy and intelligence as possible," it is still worthless from its superficiality. And so, court frivolities and the trumperies and trivialities of personal incident are the deep things for which the "historical sense" must make research, while the investigation of principles and laws is the worthless work of shallow scientists! That will do for Mr. Gibson. Let him return to his dust-holes and rubbish-bins, and enjoy their obscurities and confusions as the profundities of history. We should not have meddled with him on his own account, but Mr. Spencer's work is a challenge to his party, and we were interested in seeing what they would do about it. Their champion has done the best and the only thing that he could, and that is to merge his attack upon Spencer into a final assault upon science itself.

We reproduce on another page the brief but suggestive address of Mr. George Ripley, upon laying the corner-stone of the new *Tribune* building. It was fitting that the paper which was founded by Mr. Greeley, and devoted to progressive ideas, and which has had so wide an influence in educating the American people, now that its founder and master-spirit has passed away, should be solemnly rededicated to the continued advance and diffusion of liberal thought and growing knowledge. A political partisan press we must, undoubtedly, continue to have, just as we must have war, pestilence, crime, corruption, and other evils; but it is coincident and will be coterminous with public ignorance, shortsightedness, and the general reign of demagogism. We accordingly hail with pleasure every indication of revolt against party domination, and the increasing recognition of those wider and deeper interests with which the permanent prosperity of society is involved. In the diffusion of science in cheap popular forms, the *Tribune* has always taken a leading part; and its recent efforts in this way add strength to the pledge now offered, that the same policy will be pursued in the future. In a few compressed sentences Mr. Ripley happily sketches the recent movements of philosophic thought, and discerns the full significance of that latest and largest synthesis of ideas to which scientific inquiry has brought the foremost minds of the age. Nothing is more significant of positive intellectual advance than to see a great newspaper, immersed as it must be in the practical concerns of daily life, yet holding its course in the world of thought by the higher lights of science and philosophy. The career and character of this journal have undoubtedly been, in a large measure, determined by the active mind of Mr. Greeley; but no estimate of its public influence would be just that should omit the prolonged and distinctive labors of its able literary editor, now president of

the *Tribune* Association. For twenty-five years Mr. Ripley has interpreted the intellectual work of the age through its columns to millions of his countrymen; and this has not only been done with conscientious fidelity and rare discrimination, but with a broad and courageous liberality and a catholic sympathy with all that seemed true and excellent, whatever its source. May the paper, in the new epoch upon which it has entered, have all the success that shall be commensurate with its nobleness of aim, and its honorable and high-toned management!

DEATH OF DR. LIVINGSTONE.

TIDINGS of the death of Dr. David Livingstone, the celebrated African explorer, have been received, and are generally credited. The particulars are meagre and uncertain, but it is said he died of dysentery after severe exposure, returning from Ujiji to Unyanyembe. The expedition of the British Government, under Lieutenant Cameron, is supposed to have met him in an encampment where he breathed his last, and embalmed his body to be taken to Zanzibar.

He was born in 1817, of poor Scottish parents, and, having a taste for books, his father helped him to attend the Glasgow University in the winter, while he helped himself by working in the cotton-mills in vacation. He studied medicine, and was admitted to general practice in surgery and physic in 1838. He desired to go to China as a missionary, but, hearing that a medical agent was wanted for the African missions, he applied, was accepted, ordained to preach, and in 1839 left for Natal. He here met the missionary, Rev. Mr. Moffatt, and married his daughter, by whom he had two sons born in Africa. His first effort at exploration was in the great Kalahari Desert in 1849, when he discovered the Zonga River, and floated down its current into Lake Ngami, the most southerly of that great chain of lakes which occupies the centre of Africa. The next year he returned to this lake with wife and children, who suffered greatly. He afterward discovered the great Zambezi River, the chief stream of Southern Africa. He now formed the scheme of opening up the Zambezi by means of light steamers, and of evangelizing the inhabitants of the region. His family were sent to Europe, and he undertook a formidable search of this country in 1852. His wanderings, adventures, and discoveries, were continued until the latter part of 1856, when he returned to Europe, and was received with the greatest honors. In 1857 he published a narrative of his travels, and in 1858 returned to Africa to explore the Zambezi with steam-launches. During this expedition he discovered Lakes Nyassa and Shirvan, lost his wife, and the expedition was recalled by the Government in 1863, and he again reached England in 1864. In 1865 he left his native country for the last time, and his object was thus stated in the preface to his book on the Zambezi and its tributaries: "I propose," he wrote, "to go inland north of the territory which the Portuguese in Europe claim, and endeavor to commence that system in the East which has been so eminently successful on the west coast—a system combining the repressive effects of her Majesty's cruisers with lawful trade and Christian missions—the moral and material results of which have been so gratifying. I hope to ascend the Rovuma, or some other river north of Cape Delgado, and, in addition to my other work, shall strive, by passing along the northern end of Lake Nyassa, and round the southern end of Lake Tanganyika, to ascertain the water-shed of that part of Africa. In so doing I have no wish to unsettle what, with so much toil and danger, was accomplished by Speke and Grant, but

rather to confirm their illustrious discoveries."

Of his travels, explorations, sufferings, and adventures, during the last nine years, not much is yet known, but it is hoped that records will be found giving additional information concerning the geography of interior Africa.

DEATH OF FERNAND PAPILLON.

THE readers of the MONTHLY will be pained to learn of the recent and sudden death of this brilliant young writer, with several of whose masterly papers they have become acquainted in the pages of this periodical. He died January 2d, at the age of twenty-six, of an attack of acute peritonitis, the result of a cold contracted by attending the funeral of a friend. The son of a distinguished physician, he was born at Belfort, in 1847. He studied at the Colmar Lycée, and there acquired a taste for chemistry. He attended the chemical lectures of Würtz at the Collége de France; and, at the age of sixteen, he made full abstracts of the course, which were so well done, that Würtz sent the copy to the printer with scarcely any alteration. He was recommended by Prof. Würtz to the editor of the *Moniteur Scientifique*, and had been employed upon that journal since 1864. He pursued original work in chemical physiology, and discovered the possibility of substituting, in the bones of animals, phosphate of magnesia and of strontia for phosphate of lime. He has published several important papers besides those that have been reproduced in the MONTHLY, the most interesting of which will continue to appear in our pages. He was of very amiable disposition, strongly attached to his friends and teachers, and much beloved by all who knew him. His short career was in a remarkable degree successful, as he had attained a reputation and influence in France which is usually reached only by men in the riper years of life. His papers are being prepared for the press in Paris, and will be also separately republished in this country.

LITERARY NOTICES.

INTERNATIONAL SCIENTIFIC SERIES, NO. VII.

THE CONSERVATION OF ENERGY. By Dr. BALFOUR STEWART. With an Appendix on the Vital and Mental Applications of the Doctrine. 236 pages. Price, $1.50. D. Appleton & Co.

WE speak, in another place, of the importance of the great principle of the conservation of energy as a fundamental truth of modern science. The literature of this subject has hitherto been copious, but, as it has been mainly the product of minds engaged with the original research, it has often been so technical and complicated as to be difficult to popular apprehension. The writers have generally been too busy with the investigation to give the needed attention to the art of familiar statement. No subject was in greater need of thorough simplification and careful elementary treatment. Dr. Balfour Stewart, the distinguished physicist of Kew Observatory, and Professor of Owens College, was solicited to undertake this task for the "International Scientific Series." This he consented to do, and, although master of the philosophy, and entitled to a place among its original investigators, he has shown that he can enter into the spirit and do the indispensable work of the pure teacher. His book has been written in the simplest language, with abundant and familiar illustrations, so that the ordinary reader, by its perusal, can get a complete understanding of the elements of the subject. His volume is quite remarkable for its clearness and the success with which it explains many of the hitherto difficult parts of the subject.

Dr. Stewart, as we have said, is a physicist, and he has wisely limited himself to the operations of the law, as disclosed in physical phenomena. But, to give completeness to the volume, an appendix has been added incorporating two able essays, by distinguished men who have studied the question in its vital and mental relations. Prof. Le

Conte has revised the essay, which appeared in the November MONTHLY, on the "Correlation of the Vital with the Physical and Chemical Forces," which is here reproduced; and an able lecture by Prof. Bain, on the "Correlation of the Nervous and Mental Forces," gives an instructive view of this branch of the subject. This little volume will therefore afford a fresh and complete exposition of the elements of the subject for the use of general readers.

ON THE ORIGIN AND METAMORPHOSES OF INSECTS. By Sir JOHN LUBBOCK, M. P., F. R. S. Illustrated. New York: Macmillan & Co. 1874. 108 pp., crown 8vo. Price, $1.50.

SIR JOHN LUBBOCK is well known to the world as an archæologist and anthropologist, and perhaps less well as an entomologist. Yet he has contributed no less than *thirty-five* papers to the Royal Society, and to various magazines, on entomology, during the last twenty years; and, as he is not yet forty, we perceive that he must have studied the subject at a very early age. His first paper, "On Labidocera," appeared in the *Annals and Magazine of Natural History* for 1853.

The little work before us embodies, in a popular form, many of the more interesting results of his observations, condensed from the above-mentioned memoirs. The articles have already appeared in *Nature*, and the work forms the second volume of the "Nature Series" of books, which Messrs. Macmillan are now publishing.

The main subjects discussed are the classification, origin, and the nature of the different metamorphoses of insects; various views are traced, from the old standard "Entomology" of Kirby and Spence, one of the Bridgewater Treatises, to the more recent memoirs of Müller, Agassiz, and Packard. The intelligence of insects comes out in a remarkable light. Many of our readers will remember Sir John's tame wasp at a recent meeting of the British Association. He remarks: "We are accustomed to class the anthropoid apes next to man in the scale of creation, but, if we were to judge animals by their works, the chimpanzee and the gorilla must certainly give place to the bee and the ant." For example (page 2), the larvæ of certain insects require animal food as soon as they are hatched, and the mother-insect consequently provides them with caterpillars and beetles, by burying them in a cell, side by side with the unhatched larva. But here a difficulty arises: "If the Cerceris were to kill the beetle before placing it in the cell, it would decay, and the young larva, when hatched, would only find a mass of corruption. On the other hand, if the beetle were buried uninjured, in its struggles to escape it would be almost certain to destroy the egg." Look, then, at the wonderful, but diabolical, instinct of the creature. "The wasp has the instinct of stinging its prey in the centre of the nervous system, thus depriving it of motion, and let us hope of suffering, but not of life; consequently, when the young larva leaves the egg, it finds ready a sufficient store of wholesome food." A certain species of ants keeps *Aphides* in bondage, just as we do cows, for the sake of the honey-dew which they collect; a certain kind of red ant is indolent, and keeps black ants to do work for it. Once more, there is a kind of beetle which is blind and helpless, usually found in ants' nests; the ants care for all their wants and nurse them tenderly. These things, and much more, of the lives of insects, are told us in popular language in Sir John's book, which we recommend, not alone to the entomologist, but to the general reader.—*Quarterly Journal of Science.*

HENSLOW'S BOTANICAL CHARTS. Revised and adapted for Use in the United States. By ELIZA A. YOUMANS. Mounted on Rollers. Six in Number. Price, $18.00.

THE botanical diagrams of the late Prof. J. S. Henslow, of Cambridge University, have long had a high reputation in England for their scientific accuracy, their completeness of illustration, and their skillful arrangement for educational purposes. They consisted of nine large sheets, and were published by the Science and Art Department of the English Educational Council. After bringing out her method of elementary botany in the First and Second Books, Miss Youmans felt the need of large colored illustrations of the subject; and, as Henslow's series was the most valuable yet prepared in any country, and too expensive to

import, her publishers were induced to bring out a revised edition of them here. The English edition was defective from excessive compression, the figures often overlapping so as to produce a confused effect. In the American edition they are spread over twice the original surface, giving them much greater clearness for class-room use. Several American specimens have been substituted for English species which do not occur in this country, and the whole arrangement has been much improved.

These charts illustrate the principles of the whole science of botany. They represent twenty-four orders, and more than forty species of typical plants with all their details of structure, in such a way as to exemplify the complete organization of the science. Each specimen is first shown of its natural size and colors, then a magnified section of one of its flowers is given, showing the relations of the parts to each other. Separate magnified views of the different floral organs, exhibiting all the *botanical characters* that belong to the group of which it is a type, are also represented. All varieties of botanical structure, in leaf, stem, root, inflorescence, flower, fruit, and seed, are thus exhibited. The charts contain nearly 500 figures, colored to the life, and their purpose is not to supersede the study of living plants, but only to facilitate it. Minute parts which are often difficult to find are represented upon an enlarged scale, and thus become a guide to the study of the plant.

In her Second Book, Miss Youmans says: "Besides this special assistance in object-study, the charts will be of chief value in bringing into a narrow compass a complete view of the structures and relations of the leading types of the vegetable kingdom. In fact, they are designed to present, fully and clearly, those groupings of characters upon which orders depend in classification, while, in several cases of large and diversified orders, the characters of leading genera are also given by typical specimens. The charts will thus be found equally valuable to the beginner, the intermediate pupil, and the advanced student." A key accompanies the charts, and they can be used with any botanical text-books; and, during the season of plants, they should be upon the walls of every school-room where botany is studied.

ON INTELLIGENCE. By H. TAINE, D. C. L., Oxon. Translated from the French by T. D. Haye, and revised with Additions by the author. New York: H. Holt & Co. Pp. 553. Price, $5.

THE writings of M. Taine on art, literature, and science, have taken a high rank in Europe and in this country. Though his genius may, in strictness, be said to be artistic rather than purely scientific or philosophical, yet, in the work before us, he has shown not only a varied knowledge of the details and specialties of the sciences, but an admirable aptitude in collocating and generalizing their doctrines.

All speculation, to have any permanent value, must be based upon the natural order of things: it must be interwoven with matter, motion, and force. When the intelligence becomes a faithful mirror, and reflects the universe as it is, weighing and measuring it, real progress in thought is inevitable. Well-observed and well-digested facts, thorough and patient experiments, drawn along the varied lines of Nature, generate new and recast old ideas which open out a fresh intellectual life between the two great factors of science, man and the cosmos.

We do not claim for M. Taine any noticeable discoveries in the realm of natural facts, through either observation or experiment; but we claim that he has enriched us with many new ideas and a wealth of expression very rarely equaled. His recondite thoughts are clothed in beauty by a most exquisite imagination.

M. Taine has divided his labor into two parts, containing eight books and eighteen chapters. The first two books, on "Signs and Images," are relieved of much of their necessary subtilty by the picturesque and realistic manner of their treatment. His words are never void of the kernel of the concrete, which is never overshadowed by abstractions. The various objects of the external world and their permanent relationships are physiologically gathered up by the five senses, and require to be properly named or labeled before entering into the laboratory of thought. For this purpose signs are deftly woven together and become indispensable as servants of the mind. This

may be called the art of naming. The accumulated materials of the senses are, through a certain chemistry of the nerves and brain, photographed as *images* on the mind, and these enable us, through the means of *signs*, to dissect and put into logical sequence the whole order of Nature. What we have in our minds, says M. Taine, when we conceive general qualities and characters of things, are signs and signs only. Signs or words, therefore, branch out of sensations, and, to be of real value in the organization of knowledge, these must originate from healthy and well-regulated senses and sound cerebral functions. The immutability of the external order of things in Nature is the only sure corrective of all the aberrations and errors to which the internal condition of man, as a reflecting medium, is subject.

Books III. and IV., concluding the first part, treat of sensations and of the physical conditions of mental events. In the discussion of these topics M. Taine is fortified by the leading writers of France, England, and Germany, to whose important authority he adds much original thought, and unties many a perplexing knot by his well-directed and practised ingenuity. In the second part of his work, M. Taine treats, in the first book, of the general mechanism of knowledge; in the second, of the knowledge of bodies; in the third, of the knowledge of mind; and in the fourth book, of the knowledge of general things.

MEN AND APES; an Exposition of Structural Resemblances and Differences, bearing upon Questions of Affinity and Origin. By ST. GEORGE MIVART. New York: D. Appleton & Co., 1874. Price, $1.50.

MR. ST. GEORGE MIVART, best known as an opponent of Darwinism, strictly so called (but not of evolution), has in this work examined into the relations of man and the apes as well as other primates. In a first chapter, he gives a summary of the "external forms, habits, geographical distribution, and classification," of the primates; in a second, the "external skeleton (skin and hair) and internal skeleton (the bones)" are examined; and the last or third chapter is devoted to the consideration of the "nervous system, visceral anatomy, summary of characters, and questions of affinity and origin." He admits, with all competent naturalists, that man is most nearly allied to the apes, that is, the group composed of the gorilla, chimpanzee, orang-outang, and gibbons: the difference, then, between Mr. Mivart and others is as to the special form of apes that man is most allied to. In order to solve this question, he successively recapitulates the characters common to man and the several forms referred to, as well as the main points of difference. His results are rather negative than positive: he entirely rejects the claim made on behalf of the gorilla to nearest kinship, but does not positively claim such rank for any of the other forms, although evidently disposed to regard the affinity at least as great between the gibbons and man as with any of the other forms; he is more reserved, however, in this respect than on a former occasion. Adopting the general theory of evolution, he applies it, so far as the *body* is concerned, to man, but he claims that in his case a specific *creation* has been manifested by the endowment of that body with a *soul*.

A DICTIONARY OF MEDICAL SCIENCE, WITH THE ACCENTUATION AND ETYMOLOGY OF THE TERMS, AND THE FRENCH AND OTHER SYNONYMS. By ROBLEY DUNGLISON, M. D., LL. D. Enlarged and thoroughly revised edition, by Richard J. Dunglison, M. D. Philadelphia: Henry C. Lea, 1874.

FOR forty years this work has been an accepted authority in the hands of the profession, both here and in England. It was originally made in obedience to the demand created by the rapid advance of medical science, and how well it fulfilled its intended purpose is attested by its long and steady popularity. The present edition — the preparation of which was begun by the author, but, owing to his death, was finished by his son—is much enlarged, including more than six thousand subjects and terms not embraced in the last, and making altogether over a hundred pages of new matter. The book is something more than a dictionary. Besides the derivation, pronunciation, synonymy, and technical definitions of medical terms, it gives, under the appropriate heads, a large amount of valuable practical information which, from its conciseness and ready accessibility, cannot fail to be of great service to the physician. The typographical arrangement has also

been somewhat changed, heavy type being employed for the leading terms, while synonyms and subordinate words are put in small capitals — a modification which affords greater facility of reference. Taken as a whole, the work is much superior to any other of the kind we know of in the language, and no medical library can be considered complete without it.

SCHEM'S STATISTICS OF THE WORLD. Edited by Prof. ALEXANDER J. SCHEM. New York: G. J. Moulton, 1873.

THIS is a semi-annual publication, giving the facts and figures of the world's affairs, boiled down even to the point of desiccation. The matter is arranged in the form of tables, giving, for each country, its area, the name of its present ruler, population, debt, army and navy, imports and exports, products, coin values, weights and measures, capitals, and principal cities, together with railway, educational, and religious statistics. The facts, we are told, are collated from the latest reports, and the method of presentation, so far as convenience is concerned, appears to be a good one. With all its concentration, however, we notice some apparently needless repetitions. For example, after giving a list of the successful presidential candidates in the United States, from the foundation of the government, with the vote cast for each, their names are given over again on another page, with the State they were from, and the time of service of each, information which might more properly have gone into a single table. An excellent feature is the comparison of the weights and measures of each country with the French and English standards; their coin-values are also given in dollars and cents.

PUBLICATIONS RECEIVED.

On the Early Stages of Terebratulina Septentrionalis. By Edward S. Morse, Ph. D. 10 pages, with Illustrations.

Transactions of the American Society of Civil Engineers. November, 1873. 48 pages.

A Description of New Instruments for making Examinations and Applications to Cavities of the Nose, Throat, and Ear. By Thomas F. Rumbold, M. D. St. Louis, 1873. 16 pages, with Illustrations.

Bulletin of the Buffalo Society of Natural Sciences, vol. i., No. 3, pages 129–184. Illustrated.

The Function of the Eustachian Tube. By Thomas F. Rumbold, M. D. St. Louis, 1873. 40 pages.

Second Biennial Report of the San Francisco Park Commissioners for 1872–'73. San Francisco, 1874. 94 pages. Illustrated.

On the Structure and Affinities of the Brontotheridæ. By Prof. C. C. Marsh. 8 pages. Illustrated.

Johnston's Dental Miscellany. A Monthly Journal of American and Foreign Dental, Surgical, Chemical, and Mechanical Literature. New York, January, 1874, vol. i., No. 1, 38 pages.

On the Geology of Western Wyoming. By Theo. B. Comstock, B. S. 8 pages.

Transactions of the Michigan State Medical Society. Lansing, 1873. 170 pages.

The Larynx the Source of the Vowel Sounds. By Thomas Brian Gunning. New York, 1874. 29 pages.

MISCELLANY.

England and America.—Prof. Tyndall writes as follows to the editor of the London *Daily Telegraph:* Sir—You have given me a challenge, to which I willingly respond. In a speech, to which I had the honor of listening just before my departure from America, Hon. William M. Evarts used these words: "There is a generous and perfect sympathy between the educated men of England and the educated men of the United States. The small matters of difference and political interests which divide these two great countries are nothing to the immense area of uniform and common objects and interests which unite their people."

On the same occasion, Dr. John W. Draper, celebrated alike as an historian and scientific discoverer, concluded a speech in these words: "Nowhere in the world are to be found more imposing political problems than those to be settled here—nowhere a greater need of scientific knowledge. I am

not speaking of ourselves alone, but of our Canadian friends on the other side of the St. Lawrence. We must join together in generous emulation of the best that is done in Europe. In her Majesty's representative, Lord Dufferin, they will find an eager appreciation of all that they may do. Together we must try to refute what De Tocqueville has said about us, that communities such as ours can never have a love of pure science. But, whatever may be the glory of our future intellectual life, let us both never forget what we owe to England. Hers is the language which we speak, hers are all our ideas of liberty and law. To her literature, as to a fountain of light, we repair. The torch of science that is shining here was kindled at her midnight lamp."

The President of Cornell University, to which Mr. Goldwin Smith belongs, used, on the same evening, these remarkable words: "We are greatly stirred, at times, as this fraud or that scoundrel is dragged to light, and there rise cries and moans over the corruption of the times; but, my friends, these frauds and these scoundrels are not the corruption of the times. They are the mere pustules which the body politic throws to the surface. Thank God that there is vitality enough left to throw them to the surface. The disease is below all this, infinitely more wide-spread. What is that disease? I believe that it is, first of all, indifference; indifference to truth as truth; next, skepticism, by which I do not mean inability to believe this or that dogma, but the skepticism which refuses to believe that there is any power in the universe strong enough, large enough, good enough, to make the thorough search for the truth safe in every line of investigation; next, infidelity, by which I do not mean want of fidelity to this or that dominant creed, but want of fidelity to that which underlies all creeds, the idea that the true and the good are one; and, finally, materialism, by which I do not mean this or that scientific theory of the universe, but that devotion to the mere husks and rinds of good, that struggle for place and pelf, that faith in mere material comfort and wealth, which eats out of human hearts all patriotism, and which is the very opposite to the spirit which gives energy to scientific achievement. . . . I believe that the little army of scientific men furnish a very precious germ, from which better ideas may spring; . . . and I trust that love, admiration, and gratitude, between men of science on both sides of the Atlantic, may add new cords and give strength to old cords which unite the hearts of the two great English-speaking nations."

On the same occasion, in reference to the question of international amity, I ventured to say this much: "Among the motives which prompted me, at the time of accepting your invitation, was this: I thought, and friends of mine here thought, that a man withdrawn from the arena of politics, who had been fortunate enough to gain a measure of the good-will of the American people, might do something toward softening political asperities. I referred to this point in Boston, but my references to it have grown more and more scanty, until, in the three cities last visited, they disappeared altogether. And this not because I had the subject less at heart, but because, as your great countryman, Emerson, might express it, any reference of the kind would be like the sound of a scythe in December, entirely out of place. During my four months' residence in the United States I have not heard a single whisper hostile to England."

This, sir, will sufficiently indicate to you my experience of the feeling of the people of the United States toward this country. Either they do not hate us, as alleged; or, if they do, the manner in which they suppressed this feeling, out of consideration for a guest, proves them to be the most courteous of nations.

I am, sir, your obedient servant,

JOHN TYNDALL.

ATHENÆUM CLUB, *Saturday, Jan. 17th.*

Population of New Guinea.—Captain C. J. Moresby, of the British Navy, who visited New Guinea during the past year, to complete the unfinished survey of the late Captain Owen Stanley, reports that the whole coast country of the eastern half of that island is well peopled with a copper-colored race, quite distinct from the black Papuans of the western portion. This lighter-colored race are a friendly and intelligent people. They gladly received their strange visitors at their villages, and the crew of Captain

Moresby's vessel mixed freely with them. They practise several useful arts, such as pottery, and possess extensive well-fenced plantations.

Several attempts were made to reach the mountainous interior, by ascending the rivers emptying into Redscar Bay, but the boats were in every case brought to a stand by the increasing velocity of the current, after the first thirteen or fourteen miles. Farther east a fine port and inner harbor were discovered, and named Port Moresby and Fairfax Harbor. The southeastern extremity of New Guinea was found to have the form of a fork, off the lower tine of which lies a group of islands, but leaving a deep navigable channel between them and the main-land. Captain Moresby doubled the northern extremity of the fork, and found the northern coast of New Guinea washed by a grand, clear, reefless sea. The natives here were of the same Malayan or Polynesian race as those of Redscar Bay, and the hill-slopes near their villages were terraced and cultivated to a great height, in a manner that even a Chinaman might envy. With these people the intercourse of Captain Moresby's men was of a most satisfactory, pleasant nature. Pieces of hoop-iron were the medium of exchange, with which the crew purchased food and curiosities, including specimens of their handsome stone hatchets.

Prof. E. L. Youmans—

My dear Sir: Be so kind as to allow me room for a word in relation to the article "The Great Cemetery in Colorado," in the last number of this magazine. It was already in print when my attention was called to Prof. O. C. Marsh's article in the *American Journal of Science and the Arts*, "On the Structure and Affinities of the Brontotheridæ," in which the professor says of *Symborodon* and *Miobasileus*: "Both names should be regarded as synonyms of *Brontotherium*." While I would avoid as sheer officiousness the intrusion of one word as arbiter, yet I cannot permit the apparent discourtesy to rest upon me of even so much as seeming to ignore the professor's statement. I suppose that Prof. Marsh is entitled to be regarded as the discoverer, in 1870—and pioneer explorer then and in 1872—of that wonderful burial-place, whose dry bones you did me the honor to assign the task of imbuing with enough of life to make them presentable to your many readers. Hence any thing from Prof. Marsh on that theme is worthy of far more than ordinary consideration.

Let me here correct a typographical error. In my article, on page 475, the first word in line twelve from the bottom of the page, "Eobasileus" should read "Miobasileus."

Very respectfully yours,

Samuel Lockwood.

January 24, 1874.

Autopsy of Agassiz.—Autopsy by Drs. R. H. Fitz and J. J. Putnam; present, Drs. J. B. S. Jackson, J. Wyman, C. Ellis, M. Wyman, S. G. Webber.

Frame large. Fatty tissue abundant. Cranium, brachycephalic, falling off abruptly from the middle of the sagittal suture. Greatest antero-posterior diameter, 197 millimetres; greatest lateral diameter, 163 millimetres—these measurements made before the removal of the skin. Depth of frontal bone, measured externally at the median line, $5\frac{1}{2}$ inches = 135 millimetres; length of sagittal suture, 5 inches = 128 millimetres. The walls of the skull were thick and heavy; the dura mater exceedingly adherent to the bone and remarkably thick. The pia mater moderately transparent. Along the arachnoid veins were white lines indicating chronic thickening; the veins themselves rather more injected than usual. The cerebral sulci were deep and wide. On each side of the median line, near the anterior ascending convolution on the left, and the posterior ascending convolution on the right, was a depression which might have held a prune-stone or a little more. The brain-tissue around was diminished without evidence of disease. The arteries at the base of the brain showed evidence of extensive chronic disease of their lining membrane, with narrowing of the calibre of the carotids. The basilar artery was apparently a continuation of the left vertebral alone, the right vertebral being represented by an exceedingly small vessel which united the basilar with the inferior cerebellar, the latter being merely the prolongation of the exceedingly small right vertebral. The left vertebral was larger

than usual—larger even than the basilar. In these unusually-arranged arteries were very important changes. Commencing at an inch below the anterior edge of the pons Varolii and extending downward, the walls of the left vertebral artery were stiff, in part calcified, and its linings loose. At half an inch from the point just mentioned, immediately over the left olivary body, was a reddish-yellow, opaque, friable plug (thrombus), completely obstructing the vessel; still lower was another more recent, but probably *ante-mortem* plug. The first was one quarter of an inch long, the second four inches long. A third plug, an inch long, was above the first, and touching it. Opposite the middle of the pons there was atheromatous degeneration of the basilar artery. The walls of the internal carotids were also in part calcified. The posterior part of the right cerebellar lobe (the side on which the vertebral artery was exceedingly small) was softer than usual, the corresponding foliations swollen and indistinctly defined, indicating disease of this part, probably consequences of the changes in the arteries.

The weight of the entire brain was 53.4 avoirdupois ounces = 1,495 grammes; allowing a diminution in the weight of the brain, from the age of thirty-five or forty years, at the rate of one ounce avoirdupois for each ten years elapsed, the greatest weight of the brain may be estimated at 56.5 avoirdupois ounces.

Weight of right anterior lobe (separated with the fissure of Rolando for a guide), 234 grammes; weight of left anterior lobe, 233 grammes. Heart large, muscular fibre firm and of good color. The attached portion of the aortic valves rigid, the mitral opening large. In the left ventricle, at the lower third, a firm, organized clot of the size of a peach-stone, attached to the wall at the anterior portion near the septum; around this clot a more recent one had formed, its centre softened and granular. From this, probably, some small portions had been carried by the blood to the arteries in the base of the brain, doing their part in obstructing them and causing the fatal changes above described. The lining membrane of the heart, where the clot was attached, was much thickened, and the muscular layer at the same part very thin, near the apex not visible to the naked eye.

The lungs were adherent to the ribs on both sides of the chest—the evidence of old inflammations. The other organs were healthy.—*New York Tribune, December* 16, 1873.

A Good Hedge-Plant.—The *Gardener's Monthly* thinks that the white-thorn (*Elæagnus parvifolius*) complies with all the conditions of a good hedge-plant, much better than the Osage orange or any of the other plants employed for that purpose in this country. This plant does not grow more than a few inches high the first year from seed, and is then thornless; but there are large numbers of short branches from a quarter of an inch to two inches in length, and these become sharp spines the next year. The older the plants the spinier they become—an excellent feature in a hedge-plant. The second and third years branches are produced from three to five feet long, thus soon reaching a good height for a hedge. When the plants are massed together, they rarely show any disposition to exceed the height of six or eight feet. When they reach that height, they grow by sending strong shoots out from the stems near the ground; and thus the hedge is ever growing thicker—another excellent feature. If pruned, they make a first-class hedge; if totally neglected, they are still protective. Plants three or four years old seed, so that in a few years, with moderate encouragement, plants in abundance could be obtained.

Besides its protective value, the plant has a very beautiful appearance. The under side of the leaf, as well as the young growing branches, are silvery; and hence its common name. South of the Potomac it would probably be an evergreen. In Pennsylvania it holds its leaves to Christmas. The flowers are greenish white, not showy, but resemble in fragrance the English hawthorn. The berries which succeed are of a mottled red. The writer in the *Gardener's Monthly* is unable to determine what is the extreme degree of cold to which the plant may be exposed without injury. He states, however, that it has remained entirely uninjured in one situation when

the last year's shoots of the Osage orange and the honey locust were destroyed, the thermometer being 14° below zero. The Elæagnus is a native of the Himalaya Mountains.

Technical Education.—Dr. Lyon Playfair, in his "Lecture on Technical Education," dwells upon the success which has attended the technical institutions of Switzerland and Holland. He says: "What has enabled this little nation (Switzerland), so remote from the pathways of commerce, and so poor in the mineral resources of industry, to carry on manufacturing production by the aid of a prosperous and contented people, while England, washed by the ocean and abounding in mineral wealth, is burdened with an ever-increasing proportion of the unproductive poor? There is only one answer: that Switzerland has a highly-educated people." And of Holland he adds: "Despite her natural poverty in the raw materials of industry, Holland sends to this country alone exports of food to the annual value of £5,000,000, and manufactured products worth £6,000,000 more. The law compels every town of 10,000 inhabitants to erect technical schools." Among Dr. Playfair's conclusions, he states that "a higher education, in relation to the industries of the country, is an essential condition for the continued prosperity of the people; for intelligence and skill—as factors in productive industry—are constantly becoming of greater value than the possession of native raw material or local advantages." —*Iron.*

Science and the Press.—Remarks of George Ripley at the laying of the corner-stone of the new *Tribune* building:

"Friends and Fellow-Laborers: We have assembled to-day in commemoration of the past, and for consecration of the future. The original foundation of the *Tribune* was laid in sentiment and ideas. Horace Greeley was a man of no less profound convictions than of lofty aspirations. The tenderness of his emotional nature was matched by the strength of his intellect. He was a believer in the progress of thought and the development of science, in the progress of society and the development of humanity. Under the influence of this inspiration, the *Tribune* was established more than thirty years ago. At that time its basis was spiritual, and not material, strong in ideas, but not powerful in brick and mortar, in granite or marble, in machinery or in money. We have come to-day, not to remove this foundation, but to combine it with other elements, and thus to give it renewed strength and consistency. It is our purpose to clothe the spiritual germ with a material body, to incorporate the invisible forces which inspired the heart of our founder in a visible form, in the shape of a goodly temple, massive in its foundation, fair in its proportions, and sacred in its purposes. The new *Tribune* of to-day, like the old *Tribune* of the past, is to be consecrated to the development of ideas, the exposition of principles, and the promulgation of truth. The ceremony which is now about to be performed typifies the union of spiritual agencies with material conditions, and thus possesses a significance and beauty which anticipate the character of the coming age. The future which lies before us, it is perhaps not presumptuous to affirm, will be marked by a magnificent synthesis of the forces of material Nature and the power of spiritual ideas.

"Allow me one word in illustration of this prophecy, and I will yield the place to the fair hands and the fair spirit whose presence on this occasion crowns the scene with a tender grace.

"About ten years before the establishment of the *Tribune*, dating from the death of Hegel, in 1831, and of Goethe in the following year, the tendency of thought on the continent of Europe, which had been of an intensely ideal, or spiritual character, began to assume an opposite direction. Physical researches rapidly took precedence of metaphysical speculation. Positive science was inaugurated in the place of abstract philosophy. The spiritual order was wellnigh eclipsed by the wonderful achievements of the material order. A new dynasty arose which knew not Joseph, and the ancient names of Plato, and Descartes, and Leibnitz, were dethroned by the stalwart host that took possession of the domain of physical science. I need not rehearse the splendid discoveries which have

signalized this period. Such acquisitions to the treasury of positive human knowledge have never been made in an equal time in the history of thought. More light has been thrown on the material conditions of our existence on earth than has been enjoyed before since the morning stars first sang together. But the signs of the times indicate the commencement of a reaction. The age accepts the results of physical research, but refuses to regard them as the limit of rational belief. In resolving matter into molecules, and molecules into atoms, the most illustrious cultivators of physical science cheerfully confess that they arrive at invisible forces which no crucible can analyze, no microscope detect, no arithmetic explain. The alleged materialism of Tyndall and Huxley thus affords an unexpected support to the idealism of Berkeley.

"The *Tribune*, it may be predicted, will continue to represent the intellectual spirit of the age. Faithful to its past history, it will welcome every new discovery of truth. Free from the limitations of party in philosophy or religion, in politics or science, it will embrace a wider range of thought, and pursue a higher aim in the interests of humanity. Watching with its hundred eyes the events of the passing time, it will wait for the blush of the morning twilight which harbingers the dawn of a brighter day. As we now place the votive tablet on its rocky bed, let it symbolize the radiant scroll of human knowledge reposing on the foundation of eternal truth."

A Swarm of Locusts.—Dr. B. A. Gould, in a letter published in the December number of the *American Journal of Science*, describes a swarm of locusts at Cordova (in the north of the Argentine Republic), which, for extent, rivals those which have been sometimes witnessed in Eastern countries. He says: "I saw to the eastward what was apparently a long trail of dense black smoke extending over 160° of the horizon, from which it extended to an altitude of about 5°. The appearance differed in no respect from that of a black smoke drifting from a large conflagration. The insects were evidently transported by the wind, and passed within about three or four miles of us. Certainly twenty miles of its length were visible over the far-stretching pampas. They were seen before ten o'clock in the morning, and continued to pass with apparently undiminished numbers until daylight failed."

In about eighteen days the phenomenon was repeated. They again appeared to move before the wind, and passed through the space between the traveler and the mountains, which were twelve miles distant, during many hours. The height of the dense nucleus seemed to be not less than 2,000 feet, its width about six or seven miles. "Since I began this page," says Dr. Gould, "they have come upon us in full force, literally darkening the sun, and there is probably not a square inch of our grounds unoccupied by them."

Asphaltum Deposit in West Virginia.—Prof. W. M. Fontaine published, in the December number of the *American Journal of Science*, an interesting account of a deposit of asphalt in Ritchie County, W. Va., which is extensively mined, and is valuable as an addition to the coal used in producing gas.

It occurs in an enormous fissure in the rocks, apparently filling it, and has been worked vertically through a depth of 300 feet, and horizontally through a distance of 3,315 feet. The fissure is seldom more than four feet wide, in many places much less, and narrows, in one direction, so much as to be unworkable. In another direction it ends abruptly at the valley of McFarland's Run.

The geological position of this fissure and deposit is in the "Upper Barren Measures," above the Pittsburg Bed, which contains no coal. These barren measures are of sandstones and shales, and are horizontal. They show no break except at the mines.

About seven miles in the direction of the crevice is the line of upheaval in which occur the oil-wells of West Virginia. And, as Prof. Fontaine observes, the bituminous deposits, which lie far beneath the surface, are doubtless the source of both the oil and the asphaltum.

In the cleft the mineral closely resembles ordinary bituminous coal, but at the sides adjoining the walls it is jet black, and has a brilliant lustre. The walls of the

crevice are seldom discolored more than an inch in depth, and the mineral adheres but slightly.

The dry dust of the mine is very inflammable, and two accidents from explosion have occurred. The asphalt contains about 76 per cent. of carbon, and yields about 100 gallons of oil per ton.

Agassiz's Successor.—It is rare that the mantle of the father sits worthily on the son. Especially is this true when the father has been signally eminent in pure science. Happily, indeed, is it for America, and for biological science, that the vast plans of the late Agassiz are to be continued, as far as possible, on the grand scale upon which his great mind projected them. The worthy successor of Prof. Agassiz is his son Alexander, whose name, in zoological investigation, is already acknowledged as a bright light in the Old World and the New. One of the most thoroughly worked-out monographs, so far as it is carried, and the most sumptuously gotten up, is the one recently published by Mr. Alexander Agassiz, containing his researches and memoirs on the Echinoderms, and which won for him the first award of the Walker prize of $1,000, by the Boston Society of Natural History. Mr. Alexander Agassiz is to succeed his father in the conduct of the Penikese Normal School of Natural History. That great institution, the pride of Massachusetts, and the envy of the *savants* of the Old World, "The Museum of Comparative Zoology," at Cambridge, Mass., has been placed under the direction of Alexander Agassiz and Mr. Cary, "both of whom are thoroughly conversant with Prof. Agassiz's plans with regard to the museum, and familiar with the collections." Thus, while all must lament, as a great loss, the demise of that wonderful man, yet a deep solicitude has been removed from many minds as to the fate of the professor's plans.

Lime-Soils and the Potato-Rot.—A writer in the *Chemical News* is led, by analysis of diseased and sound potato-tubers, to ascribe the potato-rot to a deficiency of lime and magnesia in the soil. Different observers state the percentage of magnesia in the ash of sound tubers at from five to ten per cent.; in the diseased tubers analyzed by the author it was only 3.94 per cent. Analysis of sound tubers shows over five per cent. of lime, but in the ash of diseased tubers the author found only 1.77 per cent. A similar observation was made some years ago by Prof. Thorpe with regard to diseased and healthy orange-trees; in the former there was a deficiency of lime and magnesia.

It was shown, by the late Dr. Crace Calvert, that lime is one of the few known substances that are capable of altogether preventing the development of fungi in organic solutions. He does not give any experiments relating to the action of caustic magnesia on fungi; but doubtless that action will be found to be similar.

"Here, then," observes the author, "is a curious and significant fact. Diseased potatoes are deficient in lime-salts, and lime prevents the development of fungi. May not the development of fungi in the vessels of plants be furthered by this deficiency? The circumstances are such as scarcely to leave room for doubt. So far, then, theory and practice agree: lime has been found by experience to be useful in preventing the disease, and it is likely that magnesia will be found to have a similar effect."

Clay Wasp-Nests.—All the American species belonging to the genus *Polistes* (wasps) have been considered paper-nest builders; but P. R. Uhler, at the Portland meeting of the American Association, described a species which build nests of clay. This wasp is of dark-brown color, with yellow bands across the abdomen, and with yellow feet. The insect builds a nest of cylindrical shape; and a number of these cylinders were found in the stump of a decayed tree, in Charles County, Md. The central cavity of the stump—which was about five inches in diameter—contained thirty-three of these peculiar structures. They were of yellow clay, generally about half an inch in diameter, and varying from two to five inches in length.

The nest, or more properly the receptacle for the egg and young, is constructed in the following manner: The adult wasp works some wet clay into an oval pellet, and carries it to the place where the nest is

to be made. The pellet is then laid obliquely and pressed down by the fore-feet and head of the insect, so as to cause it to adhere firmly to the surface on which it is building. As it proceeds, it smoothes the inside of the cylinder by working with its jaws and pushing the front of its flat head against the plastic clay. The first section being thus finished to its satisfaction, it flies off to secure small spiders. It seizes a spider with its fore-feet, stings it in just such a way as to paralyze, without destroying its life, and then deposits it in the bottom of the cylinder.

An egg is then laid beside the spider, and the wasp flies off to secure other spiders. This is continued until the cavity, which holds from twelve to fifteen of the smaller kinds, is full. The wasp then covers the open end with a cap of the same material as before, after which it adds other sections to the number of three or four, filling each with spiders and depositing one egg in each. The young larva feeds on these paralyzed spiders, and, as it seems, requires from twelve to fifteen of them to nourish it until it is ready to become a pupa. Unlike some other clay-nest builders, this wasp does not nurse its young, but they are securely sealed up in the sections, and feed themselves. When ready to come forth, the wasp gnaws a round hole in the wall of its cell, and issues forth as a perfect insect.

The Uses of Baryta.—Baryta is an alkaline earth of a gray color, not easily fusible, and poisonous. Its various salts are extensively used in the arts, as will be seen from a paper read by Dr. Lewis Feuchtwanger, before the Polytechnic Club, of which we present a synopsis. The sulphate of baryta, 66 per cent. of baryta and 34 of sulphuric acid, is the only baryta-salt that is not poisonous. It is abundant in England, France, Germany, and the United States, where it usually occurs in connection with beds or veins of metallic ores, as gangue, or vein-stone. Sometimes, however, it forms distinct veins, in company with the secondary limestone, and very often in fine crystals, along with calcite and celestine. Connecticut and Missouri have long furnished abundant material for the arts. Next come Virginia, New York, New Hampshire, Massachusetts, Pennsylvania, Kentucky, and Tennessee. The variety known as "Bologna spar" is an ornamental stone, of a brown color, and concentric rings, originally found in a bed of clay near Bologna. The sulphate of baryta also often occurs associated with lime, and some silica and alum, and is then called calcareobaryte; when associated with strontia it is called baryto-celestine.

Witherite is a carbonate of baryta, consisting of 78 per cent. baryta and 22 carbonic acid. It is found, in considerable quantities, in England, Silesia, Hungary, Sicily, and Chili, but not much in the United States. It is largely used in plate-glass manufacture in France, as also in the manufacture of beet-root sugar, and *permanent white*. Latterly, it has come into use for paint, in combination with soluble glass and white oxide of zinc. The metallic base of these salts is barium. It is a white, malleable, and fusible metal, readily oxidizing in air, and decomposing water at common temperature. The pure baryta, oxide of barium, is used for the production of peroxide of hydrogen, which is much recommended as a medicinal reagent, and employed in the arts for bleaching animal tissue, and converting brown into blond hair. The oxide, or caustic baryta, rivals, in caustic properties, potash, soda, and ammonia.

The chloride of barium is got by fusing the sulphate of baryta with chloride of calcium, in a reverberatory furnace, and then extracting with hot water, leaving the sulphate of lime undissolved. Chlorate of baryta, used in pyrotechny, and which burns with a green flame, is prepared by dissolving artificial carbonate of baryta in chloric acid solution. Nitrate of baryta, likewise used in pyrotechny, may be got by dissolving the native carbonate in nitric acid and evaporating the solution, octahedral crystals being deposited. The native sulphate of baryta is used to adulterate white lead, often to the extent of 25 to 50 per cent.

The artificial sulphate, permanent white, is much used in the manufacture of a paper of the purest white, for collars, cards, etc. In copper metallurgical operations, the sulphide of barium has latterly been employed for the purpose of precipitating from an ammoniacal copper solution the copper as a

sulphide. The artificial carbonate of baryta, produced by passing carbonic acid through a sulphide of barium, is much used in Europe in the manufacture of achromatic glass.

Subterranean Fish.—For the purpose of supplying water to a new wharf at Point Hueneme, southeast of San Buenaventura, Cal., an artesian well was sunk not five feet from high-water mark. At the depth of 143 feet a strong flow of water was obtained, which spouted 30 feet high. A goose-neck was fitted on the bore so as to reverse the flow. One day while the agent was absent, the men noticed fish in the waste-water. On his return attention was given to the fact, and the well was found to be filled with young trout, thousands of them being thrown out at every jet. These trout were all the same size (about two inches long), and perfectly developed. *They had perfect eyes.* There is no stream nearer than the Santa Clara River, several miles distant. There are no trout in the lower portions of the river. The temperature of the water is the same as that of the wells of this country (64° Fahr.), too warm, of course, for trout to live long in.—*American Journal of Science.*

New Refrigerating Machine.—A refrigerating apparatus, invented by Captain Frederick Warren, British Navy, is described as follows: It consists of a small steam-engine, to which is attached a second cylinder for condensing ether-vapor. The cold produced by the expansion of this condensed ether is utilized by being communicated to brine contained in pipes, around which the ether circulates. The brine thus cooled is used in its turn either to freeze water or to cool air, the water being contained in reservoirs immersed in a vessel of cold brine, and the air being conveyed in pipes which wind backward and forward in the brine. The ether employed, being contained entirely in closed apparatus, is scarcely at all wasted, and little more than its first cost need be taken into account.

In the experiments made with the machine, the moisture on the outside of the pipes leading to the refrigerator was rapidly frozen, and the air of the room, after being withdrawn at a temperature of 62° Fahr., was almost immediately returned to it at 45°. As this process continued, the temperature of the room was rapidly reduced, and might easily have been brought to the freezing-point and so maintained. Captain Warren claims that the temperature of any limited space can be thus kept down to almost any required degree, and he proposes to apply the method to the construction of cold chambers on board ships, to be used for storing fresh provisions, or, in the case of merchant-ships, for the conveyance of perishable freight. He does not, however, think it possible to freeze a whole cargo of meat, so as to resist putrefaction in a long voyage, as from Australia to England. He proposes to cool railway-carriages, to provide cool vases for the conveyance of meat and other provisions in India, to cool the air admitted into hospital wards, and to provide an unlimited supply of pure ice at almost nominal cost.

NOTES.

The latest application of the sand-blast is for cleaning the fronts of buildings, by removing the soot, dust, and other substances therefrom. The impact of the sand on the surface removes the dirt from all the crevices and indentations, without perceptibly affecting the sharpness of the architectural ornamentation.

In the course of a lecture on mercury recently delivered at Vienna, the leg-bone of a man was exhibited, whose death had undoubtedly been hastened by mercury. On striking the bone heavily on the table, out fell thousands of little glittering globules, which rolled about on the black surface before the lecturer, collecting here and there into drops. This mercury had been absorbed during life, and proved the death of the absorbent.

In 1871 the census of Ceylon was taken, it being the first attempt of the kind in that island. When this measure was first talked of, a belief prevailed in the minds of the Cinghalese that it was but a preparation for the levying of a new tax. In many districts the natives said that the object was to discover the number of unmarried youths, with a view to their being deported to Europe, whose male population, they said, had been destroyed by a great war. This led to an unusual number of marriages being celebrated. The population of the islands is 2,500,000. Their religion is looked after by 5,345 Buddhist priests, 1,078 Sivite

priests, 449 Mohammedan priests, 862 devil dancers, 217 Protestant missionaries, and 87 Catholic priests. Over 1,500,000 of the people are Buddhists, nearly 500,000 Sivites, and about 183,000 Catholics, while 35,406 are parceled out between four varieties of Protestantism.

In the January POPULAR SCIENCE MONTHLY we gave the State Geologist of Minnesota as authority for the statement that iron-ore exists in vast quantities in the neighborhood of Black River Falls in that State. Prof. N. H. Winchell, the State Geologist referred to, has since written us that he never made the statement, and is not aware that iron-ore, in any quantity, is found in that locality. The item and the authority for it were taken from the *Journal of the Society of Arts*, an esteemed contemporary, which had evidently been misled like ourselves.

THE yield of gold in New Zealand up to the end of the year 1872 was 6,718,218 ounces, valued at £25,814,260, of which the north island furnished 734,269 ounces, worth £2,563,307. This gold is obtained by lode-mining in igneous rocks of the Neozoic epoch. The south island furnished 5,983,979 ounces, value £23,250,953, chiefly obtained from the metamorphic rocks by alluvial washing.

IN the competition last October for the $100,000 prize offered by the State of New York for a satisfactory application of steam-power to canal navigation, one of the competing boats, the Baxter, carrying 200 tons of cargo, and drawing 5 feet 8½ inches water, traveled about 55 miles in a little over 18 hours, consuming only 830 pounds of hard coal. None of the performances, however, were deemed satisfactory by the commissioners, and the prize was again withheld.

A CORRESPONDENT of the London *Times* communicates to that journal some interesting notes on the *Eucalyptus* as a house-plant. He says that he has several of the young trees, grown from seeds, in his house; that they grow remarkably well, are very pretty, and emit a very pleasant odor, much resembling that of the black currant. They retain their green leaves through the winter. The only objection to them as house-plants is that they become too large; but it is easy to have a succession of them by sowing seeds again. There are several varieties of the *Eucalyptus*, three of which —wattle gum, blue gum, and scented gum —the correspondent has growing, and he says that they are very much alike in all respects.

AT the recent meeting of Italian men of science at Rome, the *alienist* physicians—that is, those who make a specialty of mental disorders—held sessions of their own, under the presidency of Prof. Girolami. After a long and interesting discussion, protracted through several sessions, they founded a *Societa Freniatrica Italiana*, or Association of Alienists. This body is to assemble every third year, each time in a different city of Italy, the first meeting to take place at Imola next year. Among the subjects for discussion we notice the two following, viz.: "Uniform Classification of Mental Disorders," and "The Founding of Insane Asylums for Criminals."

BENJAMIN DISRAELI, in a late speech at Glasgow, made the significant admission that the revolutions of science within the last fifty years have had "much more effect" in moulding the world than any political causes; and that they "have changed the position and prospects of mankind more than all the conquests, and all the codes, and all the legislators that ever lived!"

BEFORE Bessemer's invention, the yearly production of steel in England was 51,000 tons; it is now 481,000 tons, or nearly ten times as much. The production of Bessemer steel in the United States for the year 1873 is estimated at 140,000 tons.

THE great work of the De Candolles, father and son—namely, the "Prodromus Systematis Naturalis Vegetabilium," which contains a description of every known species of dicotyledonous flowering plant—has been just completed. The publication of the work was commenced in 1824 by the elder De Candolle. To commemorate the completion of the "Prodromus," the Horticultural Society of Belgium has awarded M. de Candolle a special medal.

PROF. ANSTEAD thus estimates the coal-supply of the world: In the British Islands there are 12,800 square miles; in France, 2,000; in Belgium, 520; Spain, 4,000; in Prussia, 12,000; in Bohemia, 1,000; in the United States, 113,000; in British North America, 18,000, making a total of 152,520 square miles, nearly six-sevenths of which is found in America, and over five-sevenths in the United States. This does not include the 250,000 square miles said to exist in the Rocky Mountain district through which the North Pacific Railroad passes.

THE Silber light is simply an improvement in lamps and burners, which secures the most perfect combustion of the lighting materials yet attained. Air-currents are admitted both into the centre and around the circumference of the flame, and by this means the same amount of oil or gas is made to yield a much stronger and steadier light than that afforded by the appliances in common use.